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ENVIRONMENTAL RESEARCH IN THE SAMIR VALLEY OF THE HINDU KUSH, AFGHANISTAN

Final Technical Report

by

University of Newcastle upon Tyne

Editor: A. James

JUNE 1968

EUROPEAN RESEARCH OFFICE
United States Army

Contract Number DA-91-591-EUC-3941

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A. James

Newcastle-upon-Tyne University
Newcastle-upon-Tyne, England

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Expedition Members

A.D.G. Beynon, B.D.S.	- Dentist
*M.J. Earle, B.Sc.	- Geographer
O. Gilbert, B.Sc.	- Botanist
*H. Horsley, B.Sc.	- Geographer
J. Hubbick, B.Sc., Dip.Ed.	- Zoologist
J.P. Hurley, M.B.B.S.	- Doctor
A. James, B.Sc., Ph.D., Dip.Ed.	- Leader and Limnologist
Mrs. M. James, B.A.	- Quartermaster
D. Jamieson, B.Sc., Ph.D.	- Hydrologist
H. Lister, B.Sc., Ph.D.	- Deputy Leader and Glaciologist
A. Pendlington	- Electrical technician
J.H. Parry, B.A., Ph.D.	- Geophysicist

* Graduated July 1966.

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INTRODUCTION

In the summer of 1965 the University of Newcastle upon Tyne arranged to send a scientific expedition to a mountainous area in North-West Pakistan. The main aim of the expedition was to make meteorological and hydrological observations on a tropical glacier. This was intended to form part of the University's contribution to the International Hydrological Decade. Ancillary studies were to be made of other environmental features and these were to be combined with an examination of the plant, animal and human communities to give an integrated picture of the region. A preliminary reconnaissance had been made of the study area in 1963 and planning and arrangements had reached an advanced stage, when, one month before departure, the Pakistan Government withdrew permission for the expedition. An alternative glaciated region was selected for study in the Hindu Kush and application was made to the Afghan Government. I wish to acknowledge with gratitude the speed with which approval was granted.

Permission to go to Afghanistan was received on 4 June and four days later the first part of the expedition left Newcastle upon Tyne and drove to Kabul, where they were joined by a second party which had flown out. Base camp was established at 14,000 ft in the Samir Valley on 15 July and work continued there until 25 August. The parties then returned to England, the flying and driving roles being reversed. The two parties arrived in Newcastle on 6 and 29 September respectively.

It is extremely difficult for university expeditions, with such a short time in the field, to accomplish a useful programme. This difficulty was borne in mind when planning the expedition and, as far as possible, programmes were arranged which were extensions of existing studies, thus ensuring that a worthwhile result was achieved. In particular this applied to the glaciology and meteorology programmes carried out by the Geography Department. The hydrology programme was an excellent opportunity to test dilution-gauging techniques which had been developed in the Civil Engineering Department, Similar considerations applied to the work on Lichens and the Geophysical studies. The Geomorphology programme and Land Use survey were carried out by two undergraduates as part of the course work for their degrees. Inevitably some of the projects were not directly related to the work of individuals or Departments but in all cases the results have been evaluated for this report. In addition to the research work the expedition offered the customary medical services to people living in the study area. A more unusual feature was the provision also of a dental service. Both proved extremely popular and contributed largely to our good relations with the local people.

The late change of location combined with a dearth of information about the Hindu Kush aggravated our field problems. We were, however, fortunate in our choice of study area as it is of great interest to other research teams, who are concerned with the problems of water supply in semi-arid regions of increasing population pressure, of which Afghanistan is so typical. Our data may thus find an early application.

Detailed acknowledgements are made later in this Report to all the individuals and organizations who helped us.Here I would like to thank these people and many others who by their support made the expedition both possible and enjoyable.

A. James.

GLACIOLOGY REPORT I

Mass Balance of Mir Samir West Glacier

by H. Lister

Summary

The climatic snow line is a little above the highest peaks in this region (Mir Samir 5809m 35°'N70°10'E) but steep, north facing slopes provide a topographic reason for small glaciers persisting, with a snow line a little below 4900m (16,000 ft). Snow accumulation at this height averages 130gm cm^{-2}, most of this falling in late winter and spring. Gross ablation reaches 4gm cm^{-2} day^{-1}. Net ablation (July-Aug.), measured by colorimetric techniques as stream discharges from the Mir Samir west glacier, averages 3600m^3 day^{-1} = 0.9gm cm^{-2} day^{-1}. The glacier budget for the year 1965 indicates a balance between accumulation and ablation but slow recession is the average condition. Halt stages at 4800, 4600 and 4000m are interpreted from the topography. Dating of moraines by lichen distribution indicates for the highest of these a minimum age of 400 years. Minor advance and recession is suggested within this period.

Introduction

Agriculture in the semi arid climate of Afghanistan is very dependent upon irrigation. In the N.E. river discharge is kept moderately high through the growing season by melting snow from the Hindu Kush which supplied local village fields even as high as 3600m (11,800 ft) before coalescing in gorges like that of the Panjshir river which waters extensive plains to the south as it flows on to join the River Indus. The height of the climatic snow line in these mountains has risen until it is now only a little below the highest peaks. This, together with the concomittant shrinkage of glaciers has reduced the total amount of water stored in the mountains and increased the dependence for melt water upon the more ephemeral snow patches.

This section of the report describes the topographical control on snow accumulation and the regime of the Mir Samir West Glacier. Reference is made to the reports on Hydrology, Botany, Heat Balance and Geomorphology.

Topography

The general trend of the main mountain ridges is S.W. - N.E. but turretted Alpine peaks soar steeply from side ridges 1 - 2km long. The rock varies from lightly metamorphosed sediments found along the W. flank of the Samir Valley to hard gneisses and schists which are dominant elsewhere. These have well marked joint planes that weather into deep clefts and give rise to extensive block scree. The highest mountain - Mir Samir - rised to 5809m (19,060 ft) at the intersection of two ridges, the longer of which runs W.S.W. - E.N.E. (See Fig. 4.2.)

In each of the quadrants so formed, snow accumulation is sufficient to produce a glacier but only in the two N facing ones are they of any size. The largest is known as the East Glacier and is nearly 1 km^2 in area; the one to the N.W. known as the West Glacier is $\frac{1}{2}km^2$. It falls steeply (Fig. 4.6.) as an ice apron from 5080m (16,700 ft) on the N facing rock precipice (see map - Figure 1.1.). The bergschrund at approximately 5000m (16,400 ft) opens along nearly the whole length of the glacier, the surface of which slopes gently westwards from a secondary snow-collecting basin at its E. end. The average height of the glacier surface is 4870m (16,000 ft). To the north it is bounded by a low ridge which gives rise westwards to a broad lateral moraine, partly separated from the glacier by a melt stream flowing on the ice. At the western end it curves steeply to a sluggish melt water lake dammed by a terminal moraine of large sub-rounded blocks, through which the melt-water courses to a series of shallow, moraine-ponded streams that show considerable diurnal flow. (Fig. 4.5.).

A S.W. tail to the main glacier is fed by an extension of the steep north-facing snow slope and is bounded by continuous lateral and terminal moraines. This long E.N.E. - W.S.W. ridge is the topographical reason for the snow accumulation which at the present time is only just sufficient to form a glacier in the basin as its foot.

<u>Snow Accumulation and Stratification</u>

Three pits were dug approximately along the centre line of the glacier for measurement of snow stratification, density and temperature (Fig. 1.2.)

The continuity of snow layers over the greater part of the glacier can be interpreted from the vertical snow profiles. In 1965 the glacier was snow covered until near the end of August but in most years the snow on the tongue seems to melt completely and the snow accumulation season does not commence until late winter.

The sequence of snow accumulation appears to be fairly rapid over the higher half of the glacier, intermittent windy periods being indicated by thin crusts which are readily visible in the snow pits. The snow-bearing wind seems to be from the S. and W. The upper part of the glacier receives more than a metre depth of snow before much radiation melting forms ice layers.

It seems probably that in spring and early summer, cloud cover and precipitation are interspersed with bright sunshine which gives rise to a characteristic series of superimposed layers. In the pit profiles medium-grained snow, moderately compacted, gives way to loose damp snow which is then covered by crusts that can reach considerable thickness and display an undulating upper surface where wet snow and possibly some rain has fallen onto a glazed surface. An undulating lower surface of the dominant ice layers indicated radiation melting and melt water percolation into the snow beneath, sometimes giving rise to ice knuckles.

At all the pits examined, ice layers increase in frequency, thickness and continuity as the surface (summer surface) is approached. This indicates the control of radiation and decrease in precipitation.

The minimum temperature in the vertical profiles was found to be under the dominant ice layers, suggesting an early spring minimum, by which time nearly half the snow is accumulated on the middle and upper areas of the glacier.

1957 -58	58 -59	59 -60	60 -61	61 -62	62 -63	63 -64	64 -65	Mean	Glacier August 1965. Pit 1	Pit 2	Pit 3
80	30	230	90	150	100	180	160	130	119	98.5	44.5

Table 1.1. Accumulation gm cm^{-2} in Bergschrund and Snow Pits on Mir Samir West Glacier.

The bergschrund was open but in many places filled with avalanchesnow from the rock wall above; however it was possible to enter and measure the thickness of the ice between the yellow-brown discoloured layers which indicate rock dust blown onto wet, summer snow and hence delimit annual accumulation. Table 1.1. shows annual accumulation interpreted from these bergschrund measurements and compares them with the water equivalent of the snow columns examined in the pits dug in the glacier surface. From measurement of protected snow patches and the distribution of fine grained rock material on boulders and heaped cobbles, the total snow accumulation in the region of the glacier seems to reach rather more than one metre Figure1.3 shows the measured and interpolated accumulation varying with altitude over this north west facing basin. The interpolated curve of net accumulation is based upon the mean accumulation measured in the bergschrund and the increasing thickness of infiltration ice found at the snow/ice interface, which indicates a firm line a little below 4,900 m (16,000 ft.).

It will be seen that ice flow across the bergschrund and down onto the flatter part of the glacier must take place. Flow lines could be traced in the snow when viewed from a distance, but no definite crevasses were seen. Some mass transfer from the steep accumulation slopes to the lower glacier was evident in the slow trickle of melt-water, dripping in the bergschrund and flowing along the ice surface at the bottom of the snow pits. In summer, avalanches transfer some snow down the steep rock wall, but the bulk of the transfer must take place in winter when accumulation is rapid over the névé region, yet the lower snow layers retain their temperature near melting point and thus facilitate large scale sliding down from the steep rock wall.

Ablation

Thirteen flagged wood stakes (9 on the glacier and 4 in large snow patches) were set 2 in in the snow on 16th July and the snow level and density read periodically at the stakes. Figure 1.4. shows the mean values of gross ablation on the glacier which was generally between 1 and 2 g cm^{-2} day^{-1}.

Net ablation was measured as stream discharge, 100 metres from the glacier terminus, where melt water formed a wide, juvenile, turbulent stream. After some days of experimental siting, a depth recorder mounted on top of a stilling well was set up to give a record of water depth. Stream flow was achieved from this record via a stage/discharge curve for which successive gauging of stream flow was made by dilution techniqeus (see Hydrology Report).

Hourly discharge plotted from the depth record and stage/discharge curve showed minimum flow occuring daily at 10 hours local time, increasing slowly in response to radiation melting to a maximum about 18 hours. The stream never dried up though freezing at the falling surface caused trouble with the float of the water level recorder. Melt water percolated through the snow and generally flowed along the ice surface of the previous year, revealed in the pits. Hence even a sharp drop in air temperature caused only a tardy response in the stream flow the glacier behaving like a flood control reservoir.

In figure1.3 net ablation measured as stream discharge divided by the area of the glacier averages 1 gm cm^{-2} day^{-1}. Over the three weeks during which both net and gross ablation were measured, gross ablation is 17% greater. "Net ablation" is here used to mean stream discharge since the evaporation was very small in the mass balance though appreciable in the heat balance.

Mass Balance

From Figure 1.3. the product of the net accumulation and the glacier area above the firn line is 40,000 m^3 of water equivalent. To balance this amount by melting over the glacier area below the firn line requires the removal of 9.5 gm. $cm.^{-2}$. Since most of the glacier surface even in late August was still covered by winter snow it is unlikely that there would be much change in the balance for 1965. In most years however it seems that the lower glacier is reduced to bare ice by early winter. In mid July 1956 NEWBY, (1958) found about a foot (30 cm.) depth of rapidly melting snow over the lower area of the glacier.

The hyposgraphic curve in figure/1.3. shows the extensive area of the glacier between 4840 and 4870 m. Lowering of the firn line into this height interval would thus cause the glacier to advance. The high (ca. 20 m) terminal moraine about 100m from the glacier snout borders a boulder strewn basin that has every appearance of a bull-dozed hollow, at the deepest part of which, and fringing the glacier, is a shallow lake and snow patch. This hollow and the high moraine are a result in accordance with alternations of the glacier snout as the firn line pulses a few metres into the critical altitude range of 4840 to 4880 metres. From the evidence of lichens (see below), the alternations of the glacier have probably occurred during the last 400 years. Rise of the firn line to its present level of nearly 4,900 m as postulated above thus results in a slow recession.

Glacial Retreat as interpreted from Lichen distributions

by O. Gilbert

A thorough examination of lichens growing on the moraines around the west glacier suggests that a very slow retreat may recently have speeded up. The usual criteria of species number/uniform area and mean and maximum colony diameter were used in the investigation.

It is not clear what length of time must elapse before lichens start to colonise bare rock surfaces in the arid climate of Afghanistan, but it will certainly far exceed the 13 years found by PALMER and MILLER (1961) in the European Alps. The succession on Mir Samir is pioneered by the small yellow Candelariella c. aurella which develops along cracks and is soon joined by a brown Acarospora. A gradual and well defined build-up of lichen numbers then follows leading eventually to a climax community of about a dozen species on the oldest moraines (GILBERT 1967). As work progressed it soon became obvious that the lichen vegetation was richest on and around the most prominent boulders. This phenomena, well known to lichenologists is associated with their use as "bird perching stones" and may be responsible for slightly enhancing diversity on the old moraine by the lake where bird activity is highest.

TABLE 1.2.

CHARACTERISATION OF THE LICHEN ZONES

Lichen Zones (Map) (Figure 1.5.)	1	1a	2	3	4	5
No spp/unit area (1)	10	8.2	5.9	2.9	1.2	-
Acarospora of. rufa-slutacea Max diam (2)	57mm	35mm	23mm	13mm	6mm	-
Xantheria elegens	52	61	28	7	6	-
Aspicilia sp.	90	73	32	-	-	-
Candelariella c. aurella % Freq. (3)	100%	100%	90%	100%	60%	-
Acarospora cf. rufa-alutacea	100	100	80	75	40	-
Lecidea austromongolica	100	100	100	50	20	-
Xanthoria elegans	100	100	100	90	10	-
Aspicilia sp.	100	90	70	-	-	-
Lecanora melanophthalma	100	30	5	-	-	-
Lecanora muralis	80	-	-	-	-	-
Lecidea atrobrunnea	40	-	-	-	-	-

(1) 4 sq. m. of a flat topped gneiss boulder.
(2) The mean diameter of the largest colony/unit area.
(3) The percentage frequency in the proportion of the total of sample areas in which the species occurs.

The composition of the lichen assemblages mapped are indicated in Table II. It can be seen that the units are reasonably homogeneous and separated by clear cut differences. Figure 1.5. shows how the assemblages tend to lie in arcs around the snout of the glacier parallel to each other and to the receding ice front. On the northern side of the moraine the oldest stages are missing along certain stretches because at these points summer meltwater is continually acting to cause instability and erosion down the steep, boiler-plate slabs.

It is impossible to put an accurate time scale to the sequence of lichen colonisation described above, as lichen growth is closely tied up with climatic features and the two have been integrated for only a few areas. It would appear that in temperate climates crustaceous lichens of the type we are dealing with grow about 0.5 mm/year. (HAYNES, 1964). This figure, being linearly related to the mean annual rainfall, will be greatly reduced under the arid condition of Afghanistan. There is some indication that young lichens may grow faster than old ones (ABBAYES, 1951).

Having stated the limitations of the method it is cautiously suggested that the age of the terminal moraine where several of the lichen species are represented by colonies over 80 mm in diameter must be measured in hundreds of years with a minimum somewhere near 400 years. It is with even greater caution that a maximum age of between one and one half thousand years is postulated because there are reports of old lichens which have not increased in diameter for 50 years (SMITH, 1921, COOPER, 1928). It should be noted however that round Newby's Lakes (Fig. 1.1.) there are erratics from earlier stages of the glaciation which carry a better developed lichen flora with appreciably larger individuals. It is the width of Zone 5 which gives the impression that retreat may recently have speeded up; the lowest section of the glacier is now little more than a permanent snow bed.

Regional Summary

Figure 1.1. shows the approximate extent in mid August of the glaciers at the head of the Samir valley. The glaciers on the steep, north facing slopes are supplemented by avalanche snow from yet steeper slopes above and have a lower limit close to 4800m (15,750 ft.). The smaller shrunken glaciers in corries open to the west have a fairly common lower limit of 5930m (16,170 ft.). For south facing slopes the snow line is above the highest peaks.

GROTZBACH (1959) with a geographical expedition from the University of Munich gives 4,700 and 5,100m for the snow line in 1963 on north and south facing slopes of the middle Khwaja - Muhammad Mountains, which are 40 km to the north. This indicates a climatic snow line that is more than 100m higher than was drawn by Wissman on his map of snow lines in High Asia and hence Grotzbach interpreted glacial retreat.

At the head of the Samir valley an earlier halt stage of the glaciers can be interpreted over the corrie floors with a common height of approx 4600m (15,100 ft.). (See Geomorphology Report - Lister and Earle). The most advanced stage of the ice is indicated by large lateral moraines along the

Samir valley, but it is not easy to separate individual moraines of glacial evidence from soil creep and the extension of scree from the valley walls. A marked change can however be observed in the valley at 4000m (14,120ft.) where the V shape valley cross section below gives place to the U shape above and where the rock debris below, is contiguous with the steep scree that produced it and is not ridged parallel to the valley walls. These two earlier halt stages are also reflected in two remnant terraces found at intervals along the sides of the deeply entrenched Panjshir river to which the Samir river is a tributary.

The greater snow fall to the east in the Karakoram mountains produces a lower snow line e.g. 4000m on the Chogo Lungma Glacier (UNTERSTEINER 1957) but recession there too is the dominant theme. The Kolahoi northern glacier in Kashmir has retreated $1\frac{1}{2}$ miles since 1857 (ODELL 1963).

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Richardson linked two dominant characteristics in the atmosphere's behaviour - the inertial forces and the opposing buoyancy forces - in order to classify conditions prevailing in the lower air streams (SUTTON, 1953 p. 61.). The magnitude of this index and its sign depend upon the nature of the vertical gradient of temperature and wind speed; taking negative, zero or positive values in accordance with the temperature profile defines (dimensionless) unstable, neutral or stable air. This quantity is termed the Richardson number.

$$Ri = \frac{g}{T} \frac{\left(\frac{\partial T}{z} + \Gamma\right)}{\left(\frac{\partial u}{\partial z}\right)^2} \qquad \ldots\ldots\ldots\ldots (1)$$

where z is observed height
T is absolute temp.
Γ is adiabatic lapse rate $\doteq 1.0 \times 10^{-4}$ °C cm^{-1} thus neglected here.
u is windspeed at height z

It is assumed that the fluxes of heat, momentum and water vapour in the surface layer are proportionally dependent on their respective vertical gradients. This gives rise to the following expressions for heat H, vapour E, and momentum flux τ :-

$$\tau = \rho K_m \left(\frac{\partial u}{\partial z}\right) \quad \ldots\ldots (2) \qquad H = \rho C p K_H \left(\frac{\partial T}{\partial z}\right) \quad \ldots\ldots. (3)$$

$$E = -K_v \left(\frac{\partial q}{\partial z}\right) \quad \ldots\ldots\ldots (4)$$

where the constants K_m, K_H and K_v are the r espective eddy diffusivities and q is the specific humidity.

GRAINGER and LISTER (1965), using the results of expeditions to similar sites as that visited here came to the conclusion that of all empirical relations employed to describe the wind profile over the moderate range of stabilities, that directly relating wind speed to the logarithm of the height gave the best fit.

If there is similarity between the profiles of wind, temperature and humidity (RIDER and ROBINSON 1952), E and H can be determined from these mean profiles by applying the logarithmic law. This law (SUTTON 1953) is written:

$$u = \frac{u_*}{k} \ln \left(\frac{z}{z_o}\right) \qquad \ldots\ldots\ldots\ldots (5)$$

where z_o is the roughness length and u_* the friction velocity, is defined (SUTTON 1953 p. 76).

$$u_*^2 = \left|\frac{\tau}{\rho}\right|$$

Integrating (4) between heights z_1 and z_2 and assuming equivalence of K_m, K_v and K_H (RIDER 1954, PASQUILL 1949)

$$E = \frac{K_m(q_1 - q_2)}{\ln\left(\frac{z_2}{z_1}\right)} \qquad \ldots\ldots\ (6)$$

from (5) $$\left(\frac{\partial u}{\partial z}\right)^2 = \frac{1}{k^2 z^2}\left(\frac{\tau}{\rho}\right)$$

substituting in (2) :-

$$k^2 z^2 \left(\frac{\partial u}{\partial z}\right)^2 = K_m \left(\frac{\partial u}{\partial z}\right)$$

$$\text{or } K_m = k^2 z^2 \left(\frac{\partial u}{\partial z}\right)$$

subsitituing in (6) for K_m and integrating between heights z_1 and z_2 for E from (6):-

$$E = \frac{k^2 (q_1 - q_2)(u_2 - u_1)}{\ln\left(\frac{z_2}{z_1}\right)^2} \qquad \ldots\ldots\ (7)$$

H may be found similarly.

<u>Apparatus for mean values of Temperature, Humidity and Wind Speed</u>

Individual psychrometers were made for each height of measurement (CAISLEY, LISTER and MOLYNEUX, 1963) but since mean values were required, lagged thermocouples were used rather than transistors.

Wet and dry bulb thermocouples of 40 s.w.g. copper/constantan mounted on 1/32" thick bakelite strip 3/8" wide, to slide into the inner cylinder of a double concentric tube, were given an increased thermal capacity by soldering onto $\frac{1}{8}$" dia x $\frac{3}{8}$" copper rods so that 12 temperatures could be read successivley at a light point galvanometer within 1 minute, during which time the temperature of any thermocouple would not change by 0.05°C. The wet bulb, mounted down-wind of the dry bulb and covered by a linen-gauze sleeve, was fed with water from a small removable reservoir screwed under the tubular radiation screens. Air was drawn over the couples by a 16-blade fan concentrically mounted with the tubes and powered by a small 12 v. motor. The fine wire thermocouple leads were taken through a small hole in the fan housing and fixed to a terminal strip to permit thicker wire connection to a terminal box and thence to the galvanometer. This reduced the circuit resistance to permit a galvo deflection of 1.5 cm/1°C. The fully damped galvo is much quicker than a potentiometer for reading a series of thermocouples. The reference junction was kept in a vacuum flask with melting ice and a thermometer.

Psychrometer units were clamped to a vertical aluminium tube at 2, 6, 10, 30, 100 and 200 cm. and pointed up wind. When wind and sun were from the same direction, the mast was swung round a few degrees to avoid direct rays onto the thermocouples.

Cassella Sheppard cup-counter anemometers were mounted on a nearby separate mast at 20, 30 100 and 200 cm. A cup-contact anemometer was inserted into the ground to bring the cups to 10 cm. height. The contact operated a solenoid counter which was, like the cup-counter anemometer, read at the beginning and end of each run; the run being timed with a stop watch.

Thermocouples of 20 s.w.g. copper/constantan were taped to a wood rod inserted in the ground to give temperature readings at 1, 3, 6, 12 and 30 cm. depth.

Temperatures were read up and down the range of thermocouples at least twice in each run with a few minutes' interval between each series of readings. Mean values at each height were accepted as representative of the temperature and humidity profiles for the 30 minute observation period which was accompanied by the run of the wind recorded at the anemometers, from which a vertical mean profile could be drawn of wind speed.

Apparatus-Radiation

The output of a levelled Moll Pile was read on a potentiometer, the instrument being mounted vertically upwards to measure incoming short wave radiation and vertically downwards to measure reflected short wave radiation from which albedo could be found for the surface through the day.

A MONTEITH (1962) type of net flux radiometer was made of 300 turns of constantan wire 40 s.w.g. wound on a 10 cm. outside dia., 1 cm. wide bakelite annulus the outer half of which was copper plated on the wire to give a series of thermocouples. The annulus was mounted on a 1 m. long, thin bamboo arm clamped horizontally 1 m. from the ground. This was gently swung through 5° above and below the horizontal and so achieved ventilation which permitted a steady value of the net radiation flux to be read on the potentiometer. Comparison with two net flux plates calibrated at Kew and each ventilated by an electric blower, showed 0.12 g cal cm^{-2} min^{-1} per 1 mV output of the annulus. Radiation was read to accompany each set of wind and temperature profiles.

Wind, Temperature and Humidity

Figure 1.6. summarises meteorological observations made in the same valley as the glacier but 3 km. distant and 600 m. lower. High air temperature with great diurnal range, low humidity and light NW winds prevailed with small

amounts of cloud. These conditions were interrupted by shorter periods varying from a few hours in the evening to a few days, when alto stratus clouds grew from the west accompanied by more variable winds bringing snow flurries up the valleys.

Surface winds were controlled by valley direction and on the glacier light winds were common down the gently sloping surface. Wind speeds at one metre ranged from half to 4 metres $sec.^{-1}$. Wind speeds at the lower heights were thus less precise, anemometers occasionally stopping during a timed run. Ignoring these few occasions, vertical profiles of wind speed could be fitted by a logarithmic law. At the lowest speeds, winds above 10 cm. increased linearly with height. It was expected that wind speed profiles would deviate from the log law as air stability deviated from the neutral atmosphere (GRAINGER and LISTER, 1966) but the Richardson number, used as a stability index, departed little from zero for 20 or the 24 observed profiles. Thus it was surprising to find poor agreement in the superimposed profiles of wind speed, temperature and vapour pressure. The last two were very similar but a common law was not possible and a logarithmic law, which gave the best fit, was used in the estimation of fluxes for comparison in the ablation process.

Air temperatures at 1 metre ranged from +5 to $-6^{o}C$; for a melting glacier surface, air temperature gradients were low and negative (figure1.7) except with the initial change of wind direction that brought slightly warmer air and gave a little precipitation in the form of tiny ice needles that glittered magnificently as diamond dust, falling with a slightly hazy sun, from a partly clouded sky.

Above 30 cm. humidity gradients were also low and both humidity and temperature profiles displayed similar irregularity, changing in magnitude and size of slope in the first few cm. It is difficult to record wind speeds at heights of a few cm. above a natural surface and furthermore, in the data here examined, there was no record of temperatures between 10 and 30 cm. so further analysis of these profile anomalies is not warranted. Nevertheless they are not thought to be caused by odd surface obstructions, nor to be the result of instrumental error, since similar irregularities have been recorded by different observers using other instruments over a variety of cold, natural surfaces (VINJE 1964, Ed. LA CHAPELLE 1962; LISTER and TAYLOR 1961).

Only towards the end of August was ice appearing on the lowest part of the glacier tongue and this was 'infiltration ice' from the refreezing of percolated melt water through the winter's snow accumulation. The glacier surface was gently sloping with micro undulations and occasional sun cups in the coarse crystalline snow of density 0.55 g $cm.^{-3}$. Considering only the eight wind profiles with wind speed at 1 metre 2.5 m $sec.^{-1}$, the coefficient of surface roughness z_o was 0.68 cm $\pm$ 0.32. This is much higher than the z_o value generally given for a snow surface, or more frequently, snow over close cut grass (SUTTON, 1952), but is in good agreement with values observed over similar surfaces in NE Greeland (LISTER and TAYLOR 1960). However, since the majority of observed profiles had low wind speeds and the mean z_o value from all the profiles that could be fitted by a log. law was 1.0 $\pm$ 0.6 cm. this value was not used to calculate the coefficient of eddy viscosity; wind speeds at 100 and 30 cm. were used as in (7).

Profiles of temperature and vapour pressure rarely varied as the logarithm of height through the whole 200 cm. but became more linear above 100 cm. and displayed definite anomalies in the lowest few cm. It is thus doubtful whether the vertical fluxes calculated through the 100 to 30 cm. air layer can be assumed to apply through the lowest 10 cm. where the anomalies in the profiles indicated some advection. Nevertheless, in the heat balance calculations, the fluxes through the 30 to 10 cm. air layer were assumed to reach the surface.

Evaporation and Eddy Convection

Expression (7) may be rewritten with vapour pressures in place of specific humidities and separating the constants for the site:

$$E = B(e_1 - e_2)(u_2 - u_1)$$

$$\text{where } B = \frac{Mk^2}{RT\left(\ln\frac{z_2}{z_1}\right)^2}$$

and E = Evaporation in gm cm^{-2} sec^{-1}

e_1 and e_2 = vapour press in mm Hg at heights z_1 and z_2 (i.e. 30 and 100 cm.)

u_1 and u_2 = wind speed in cm. sec^{-1} at " " " "

M = molecular weight of water = 18

k = von Karman's constant ≑ 0.4

R = gas constant = 8.31×10^7 erg$^o C^{-1}$

T = air temperature in ^oK ≑ 278

d = conversion from mm Hg to dynes cm^{-2} = 1.3332×10^3

B = 11.447×10^{-6} but for E in gm cm^{-2} 30 min^{-1} (i.e. the length of a test period)

B = 2.062×10^{-3}

Similarly expression (4) expanded as expression (7) may be rewritten in the convenient form:

$$H = C(u_2 - u_1)(T_2 - T_1)$$

$$\text{where } C = \frac{\rho C_p \; k^2}{\left(\ln\frac{z_2}{z_1}\right)^2}$$

and H = sensible heat in cal cm^{-2} sec^{-1}

T_1 and T_2 = temperature in ^oC at heights z_2 and z_1

ρ = air density, which at the height of the glacier and with the mean temperature and humidity of the observation period = 7.102×10^{-4} gm cm^{-3}

Cp = specific heat of air $\doteqdot 0.2396$

C = 18.78×10^{-6} but for H in cals cm^{-2} 30 min^{-1}

C = 3.38×10^{-2}

Evaporati... was small (3.2×10^{-2} gm cm^{-2} $hour^{-1}$) even in the early afternoon with little cloud cover and wind speed nearly 3 m sec^{-1} at a 1 metre. With the up-glacier wind bringing warmer air and light precipitation there was marked condensation which reached a peak about 0900 (figure 1.10) with 4.1×10^{-2} gm cm^{-2} $hour^{-1}$.

Evaporation was only 20% greater than condensation over the total observation time, being negligible in the mass balance though of critical importance in the heat balance because of the high value of the latent heat of vapourisation of ice ($\doteqdot$ 620 cals gm^{-1}.).

The sensible heat flux was very small since gradients of temperature and wind speed were generally small; even when warm moist air, bringing light precipitation, moved up slope from the west, the sensible heat was still small as a component in the heat balance.

Conduction through the surface snow layer

Conduction of heat through the snow surface cannot be measured directly since temperature probes for measuring gradients are not satisfactory at the surface and thermopiles in the form of heat flux plate interfere with natural conditions, particularly in snow near $0^{\circ}C$ at which they rapidly become wet and useless. Hence vertical profiles of temperature for each 30 minute test period were plotted to find the gradient at 5 cm. depth (Fig. 1.7.). The mean change in temperature from the previous test to the following test was found by graphically integrating from 0 to 5 cm. depth the area between the snow temperature profiles. The heat per half hour into this 5 cm. layer was then added to the heat conducted through the bottom of this layer (Fig. 1.8). Radiation on the surface snow caused rapid heating from which meltwater percolating into the snow raised to $0^{\circ}C$ a layer that varied from approximately 12 to 20 cm. thick (Fig. 1.8.). Such an isothermal layer precluded heat conduction but changes in the thickness of this layer provided a small component in the heat balance. Vertical spacing of the thermocouples was too big below the first 12 cm. to permit accurate measurement of this change in depth of the $0^{\circ}C$ isotherm so the resulting small component of heat is included in the total error, shown as "unexplained" in the heat balance in Figure 1.10.

Radiation (Fig. 1.9.)

Albedo of short wave radiation varied between 45 and 60% which is slightly lower for a melting snow surface than observed on glaciers at higher latitudes

(LISTER and TAYLOR 1961, p. 33). However, this is in accordance with the observed decrease in albedo with increase in radiation and, as commonly found, incoming radiation was slightly increased (and albedo decreased) by the presence of small amounts of sloud. Stratus cloud provided a better reflecting surface and thus greater increase in incoming radiation (and accompanying decrease in albedo) than cumuliform cloud.

Melting

Gross ablation was measured at nine stakes on the glacier surface during July and August (see Glaciology Report I) but was too small and inaccurate for comparison with ablation calculated over 30 minute intervals. The volume of meltwater discharged in streams that joined only a short distance from the glacier snout was 73% of the gross ablation over the three weeks when both gross and net ablation were measured (see Hydrology Report). Net ablation as stream discharge and the volume of gross ablation as calculated for the micro met. intervals is shown in Figure 1.10. Of 9,740 m^3 of melt water available only 8,308 m^3 was discharged in the glacier stream in the same 24 hours, leaving 1,432 m^3 retained in the snow cover. Since the area of the glacier was 4.4 x 10^5 m^2 the water retained in the snow cover could, on refreezing, give up 25.9 g cal cm^{-2} and raise by 0.3°C the temperature of an average column of 1 cm^2 cross section and 150 cm depth, having a mass of 82.5 gm. The measured temperature rise was less than 0.1°C per day so approximately 0.27 g water was available per cm^2 column, filling part of the 55.5 cm^3 of pore space, a decrease in pore volume of 0.5% on that one day of high melt. Stream dishcarge was greatest during this time and a few days later it was noticed that snow had ablated from the glacier snout, leaving regelation ice, with a softer, wet snow surface higher up the glacier. Thus the calculated and the stake measurements of gross ablation, are in good accordance with the response of the snow surface and the net ablation measured as stream discharge.

The Heat Balance

Heat Source		Heat Sink	
Net radiation	87	Long Wave Radiation	4
Condensation	5	Evaporation	6
Forced Convection	1	Forced Convection	6
Conduction through Snow	6	Conduction into Snow	2
Unexplained	1	Melting	82

Table 2. Percentage Source and Sink of Heat Evaluated at Glacier Surface 9 - 10 August 1965

The total heat involved at the glacier surface over 23 periods of 30 minutes is shown in Fig. 1.11 and summarised in Table 2. The net radiation, as expected, was the dominant source of heat; UNTERSTEINER (1957 p. 157) found radiation supplying 88% of the heat responsible for ablation of firn at 4,000 m. on the Chogo Lungma Glacier. With the onset of warm moist air over the glacier surface e.g. from 0800 to 1030 on 10th August (Figure 1.10) the heat given to the surface by condensation became rather more important than the average conditions indicated. From the micro met. record kept at the expedition base camp (Figure 1.6.) this invasion by warm, moist air occurred during 8 of the 30 days observed. For the whole summer the heat of condensation would be lower and of evaporation higher than shown in Table 2 but because of the high latent heat, the loss by evaporation is small. Again, for the whole summer, the snow must be a heat sink only, most of the heat to raise the snow to 0°C being supplied by refreezing of percolated melt water.

In the Panjshir region the dominant source of water for human and agricultural use through the dry summer is from melting snow at successive heights. (See Land Use Report). Before the end of the summer only a few small glaciers remain in steep-walled mountain basins protected from the south (see Glaciology Report I). Melting from these small natural reservoirs helps to offset the aridity of late summer and autumn. Increasing this melt water by artificial darkening of the glacier surfaces is very possible but would be dangerous and expensive by aircraft and very demanding on human labour by any other means since it would have to be man-packed from lakes and accumulation basins a few hundred meters below the glaciers. Such interference is undesirable since the glaciers are already receding, so increasing their ablation would accelerate glacier shrinkage and remove these natural reservoirs.

Rapid run off is a far greater problem (See Hydrology Report), but the narrow steep-sided valley of the Panjshir river offers suitable sites for dams. Many small settlements high in the valley could be served by small dams across some of the tributary valleys but areas of flat land suitable for agriculture are more scarce than water.

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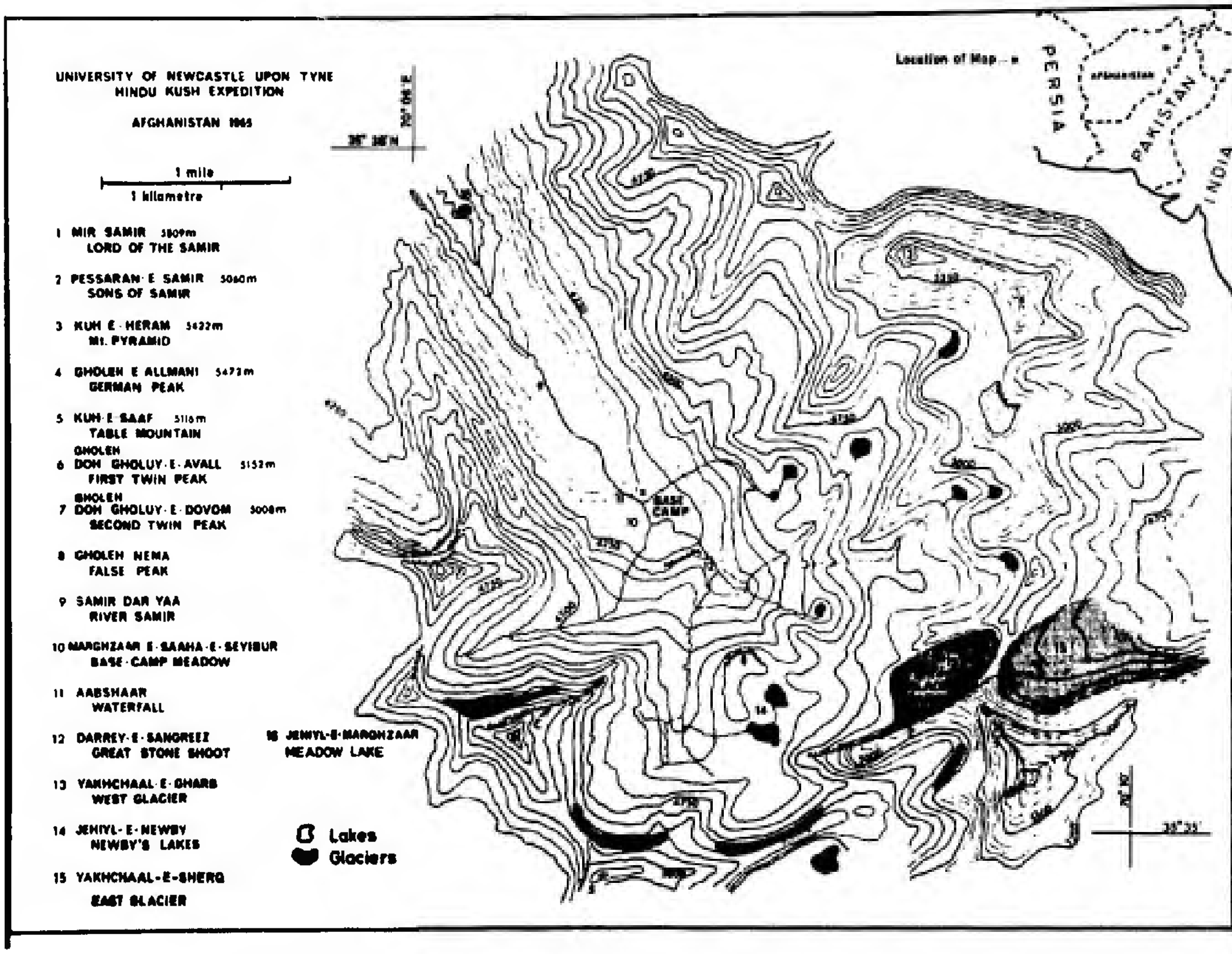

Fig.1.1. **Map of Samir Valley, showing the main topographical features and the location of the area.**

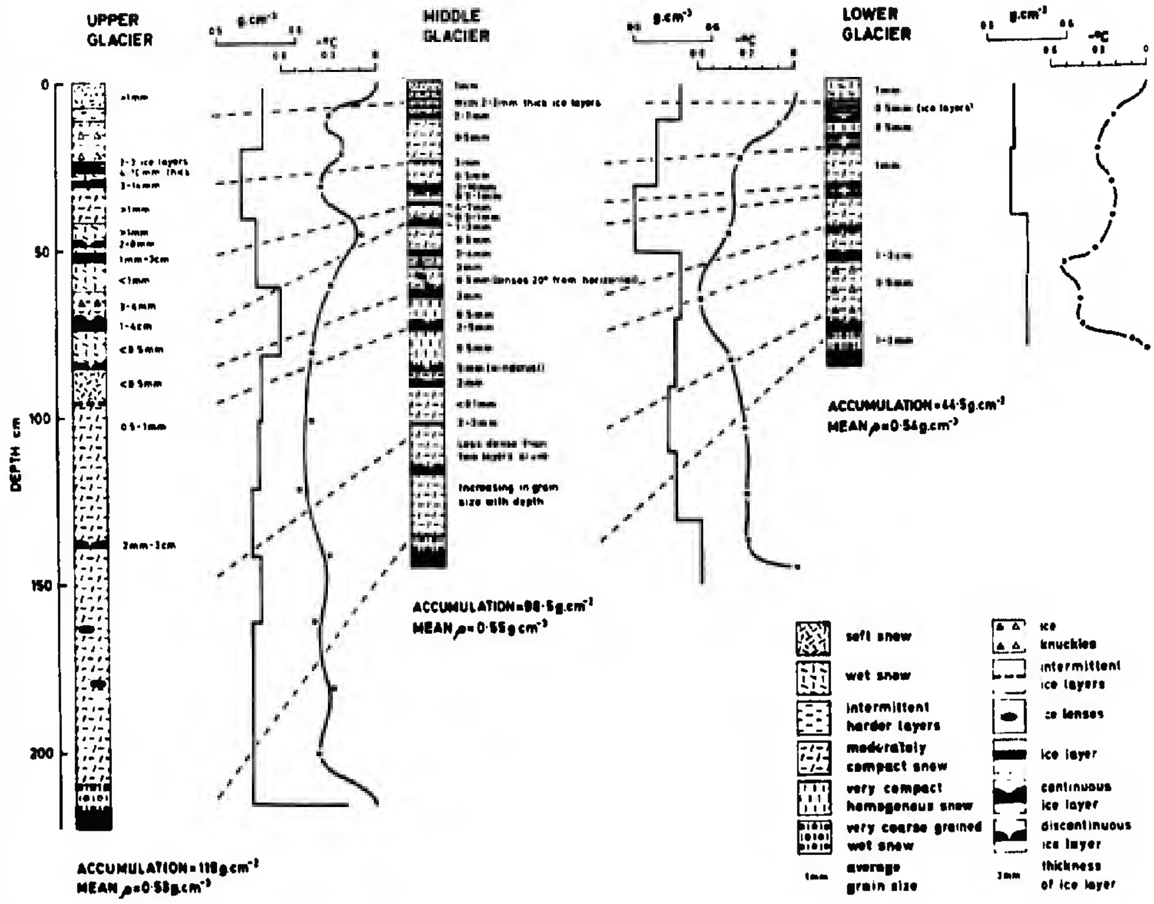

Fig.1.2. Snow stratification on Mir Samir West Glacier, July 1965.

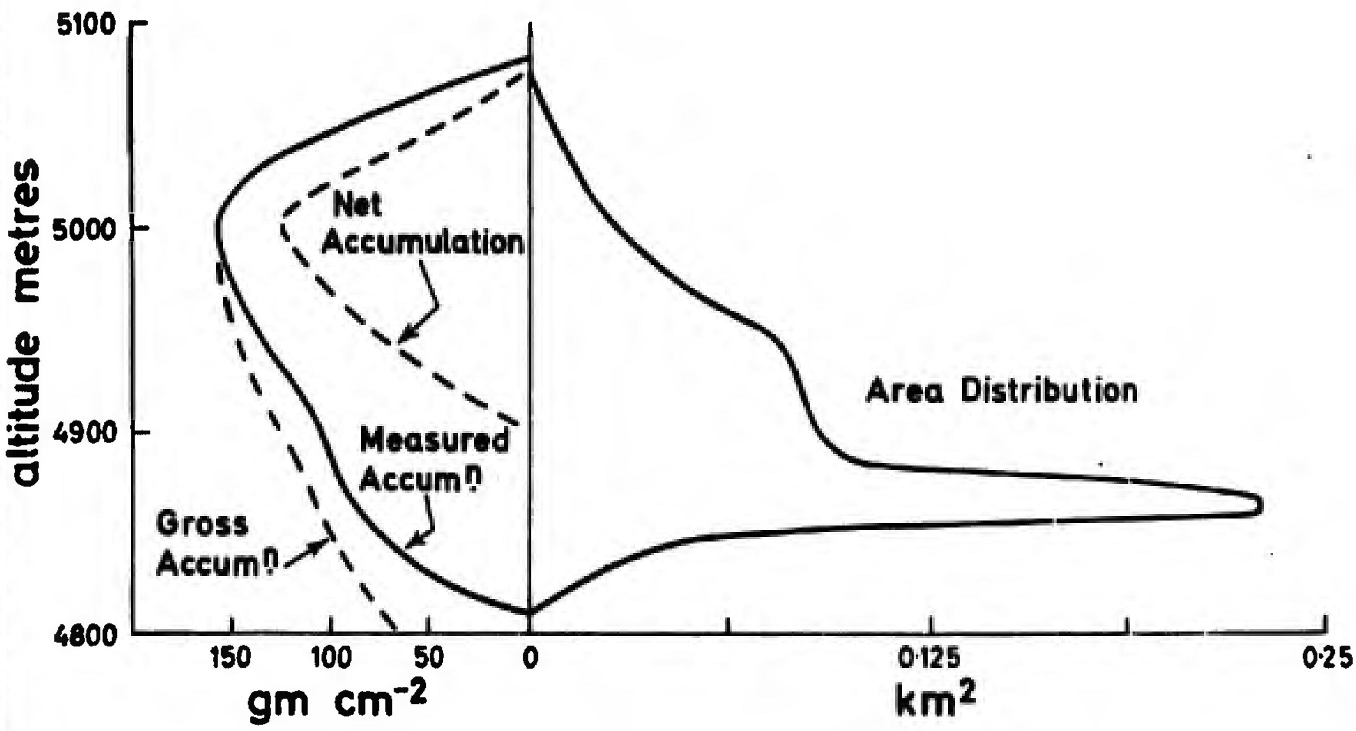

Fig.1.3. Change of snow accumulation and glacier area with height, July 1965.

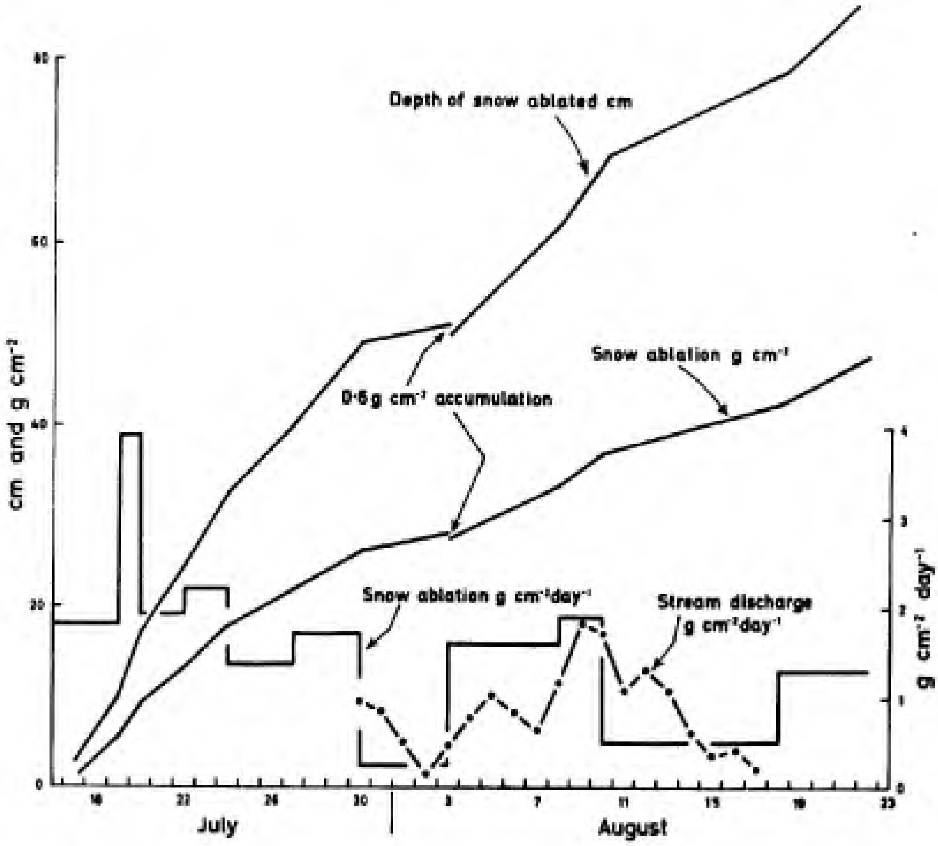

Fig.1.4. Ablation on Mir Samir West Glacier (Mean of 9 stakes), 1965.

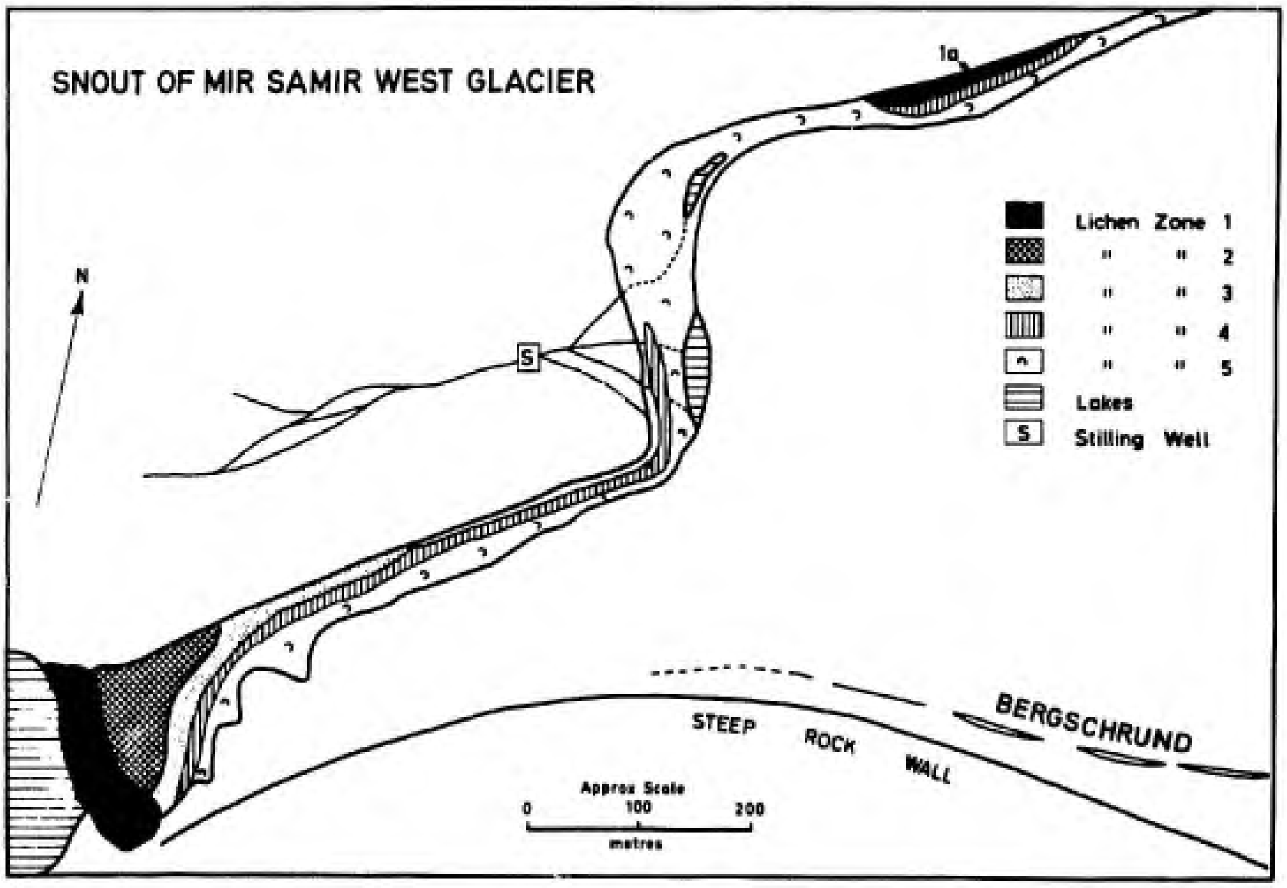

Fig.1.5. Lichen zones on moraines of Mir Samir West Glacier.

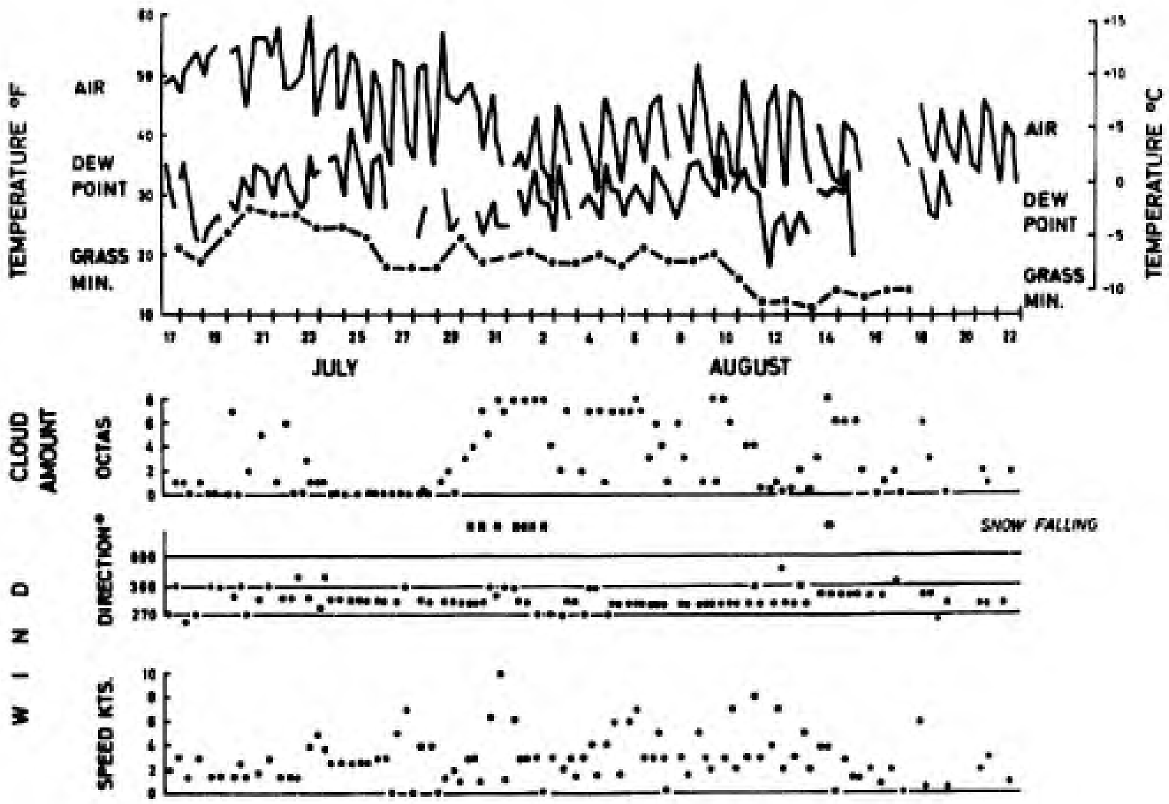

Fig.1.6. Meteorology at Head of Samir Valley 13,800 ft. (4200m), July and August 1965.

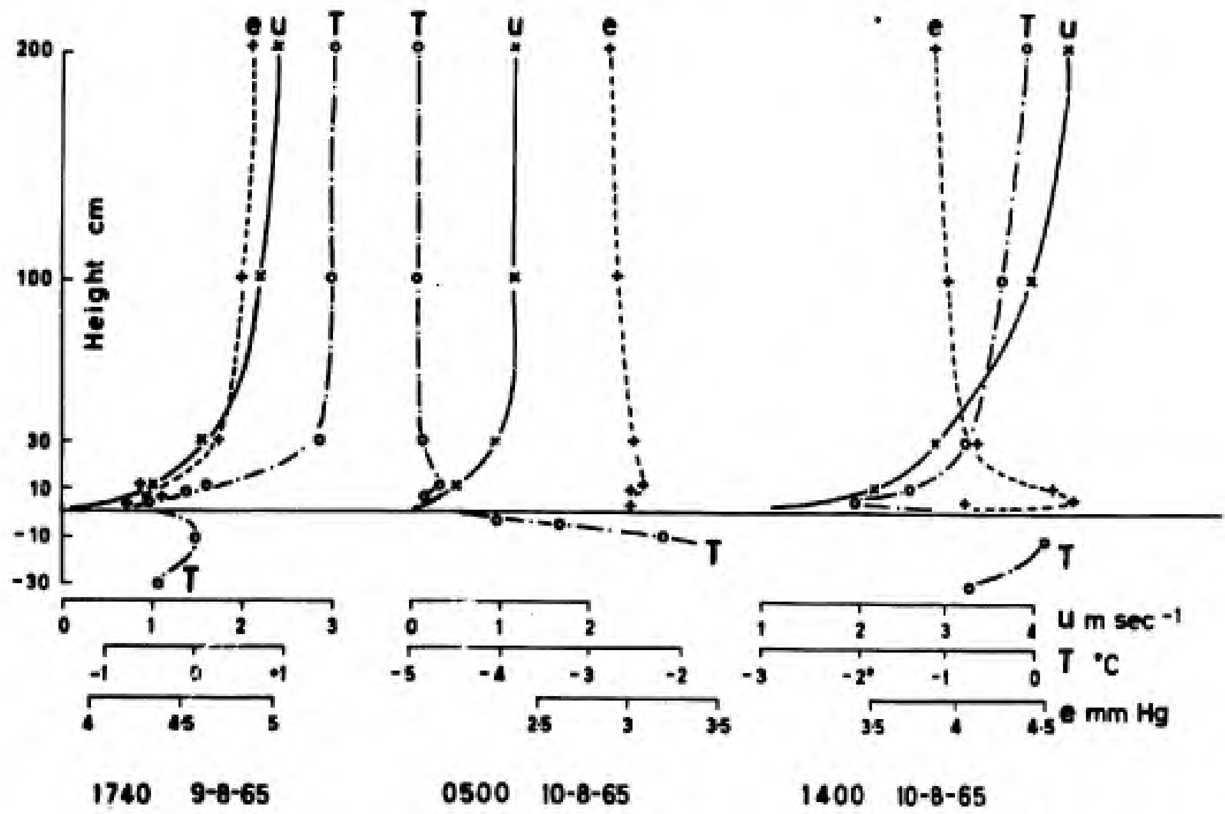

Fig.1.7. Typical profiles of wind speed u, temperature T and vapour pressure e.

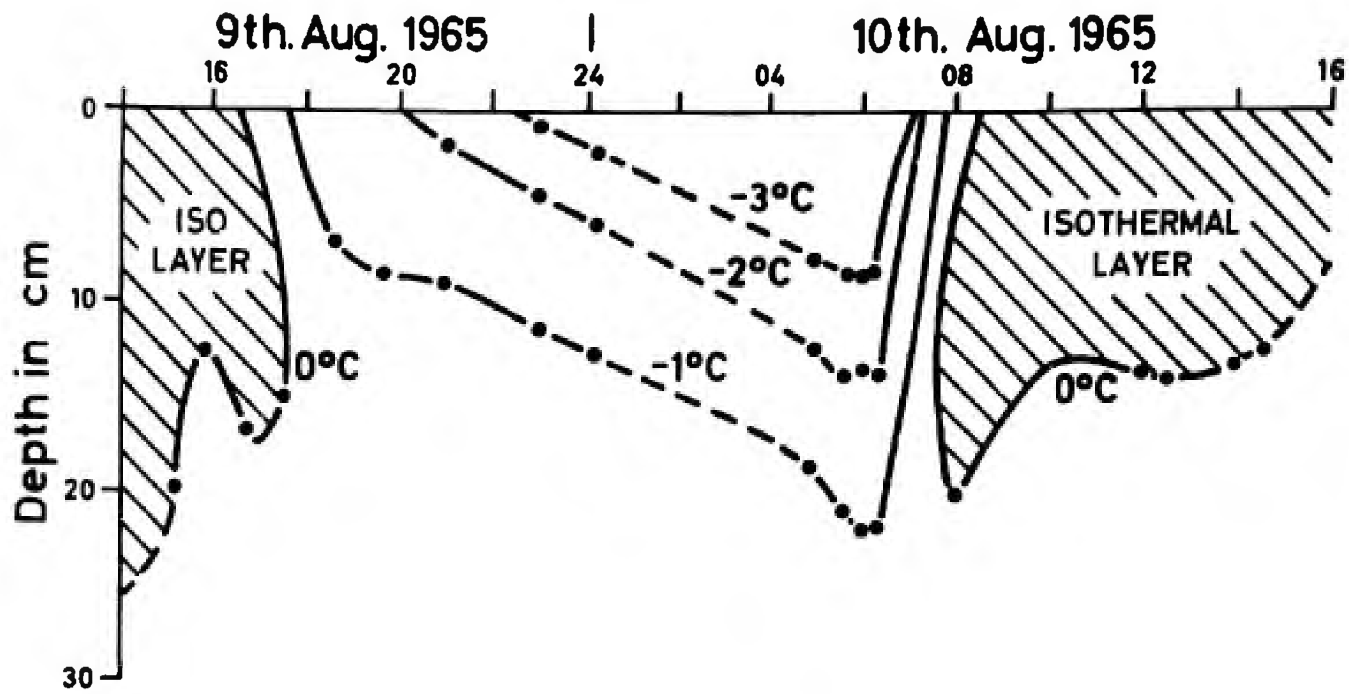

Fig.1.8. Isotherms in surface snow at the micro-met station near the centre of Mir Samir West Glacier.

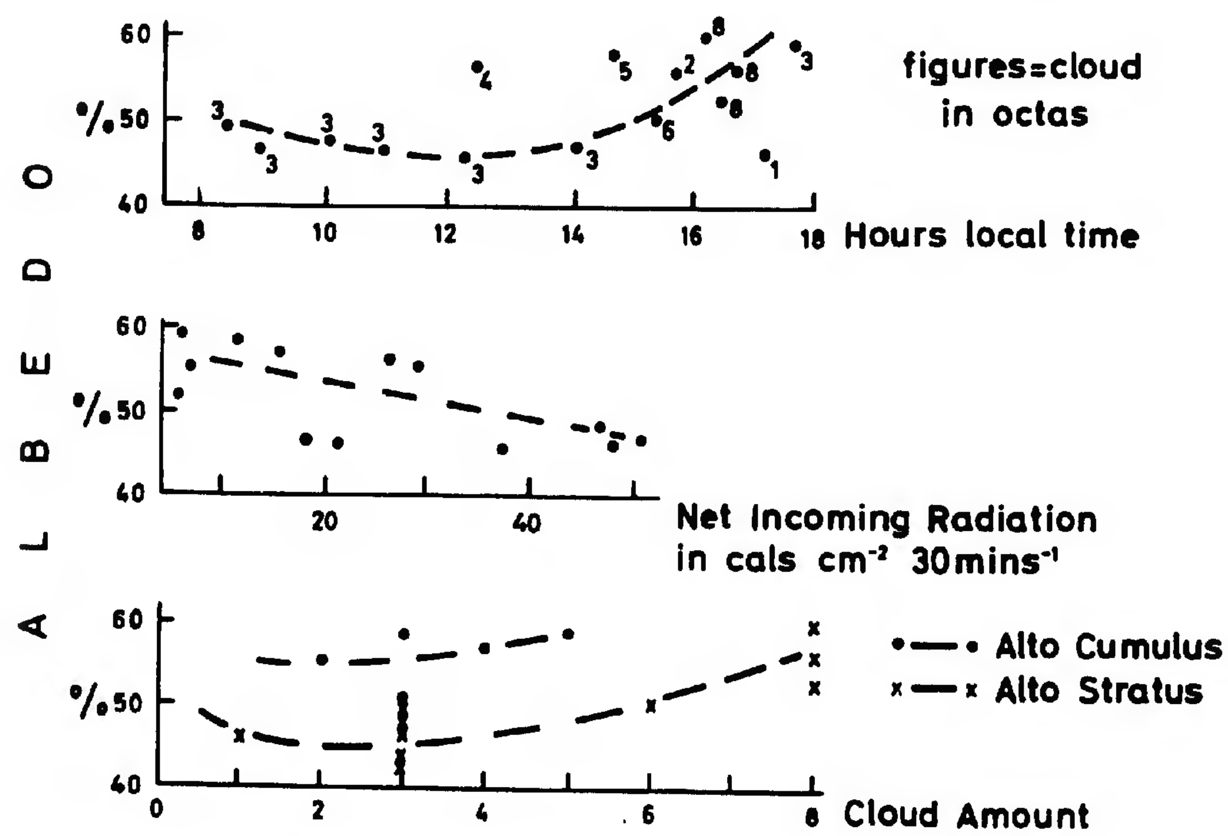

Fig.1.9. Albedo, radiation and cloud.

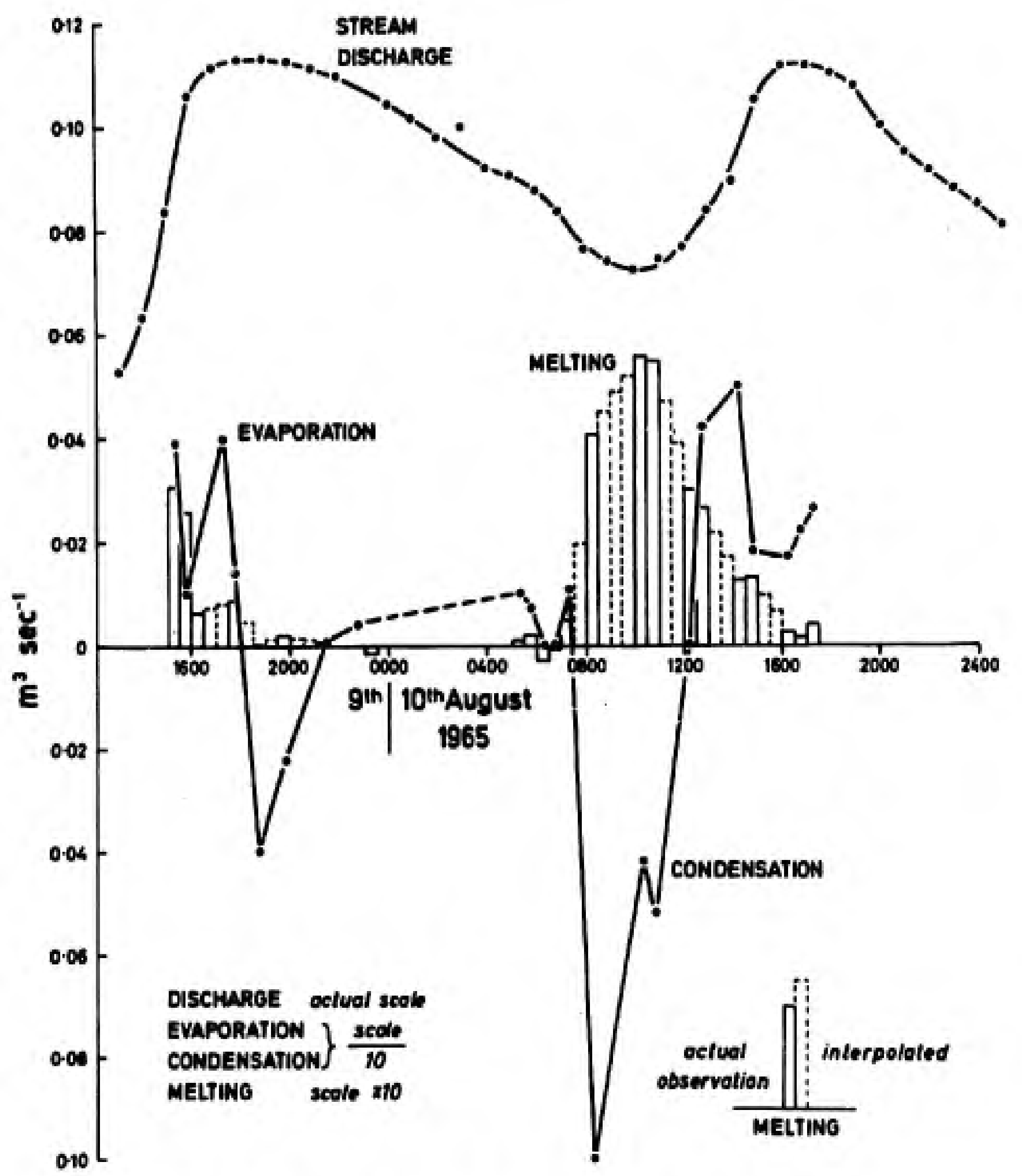

Fig.1.10. Ablation on Mir Samir West Glacier.

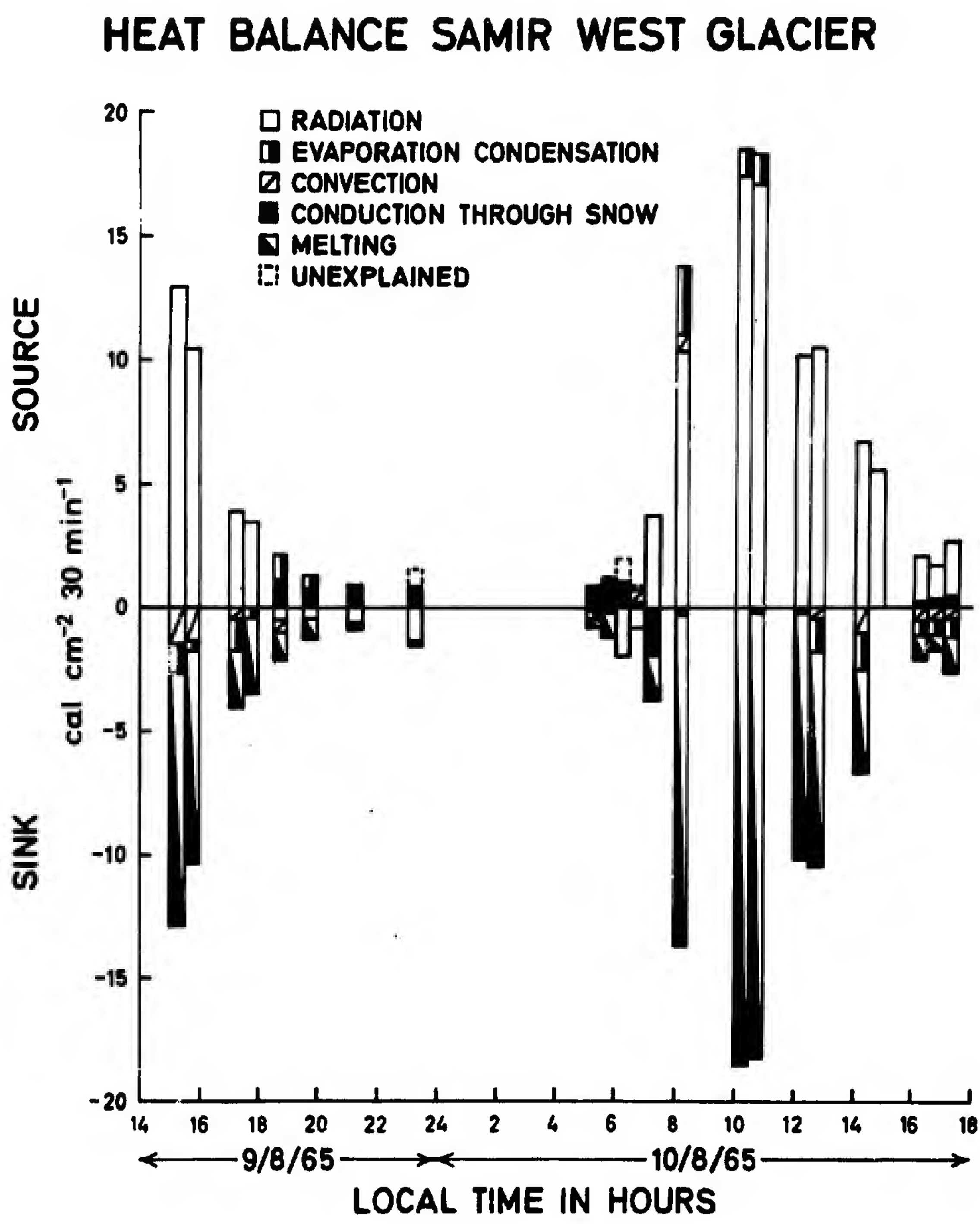

Fig.1.11. Heat balance Mir Samir West Glacier.

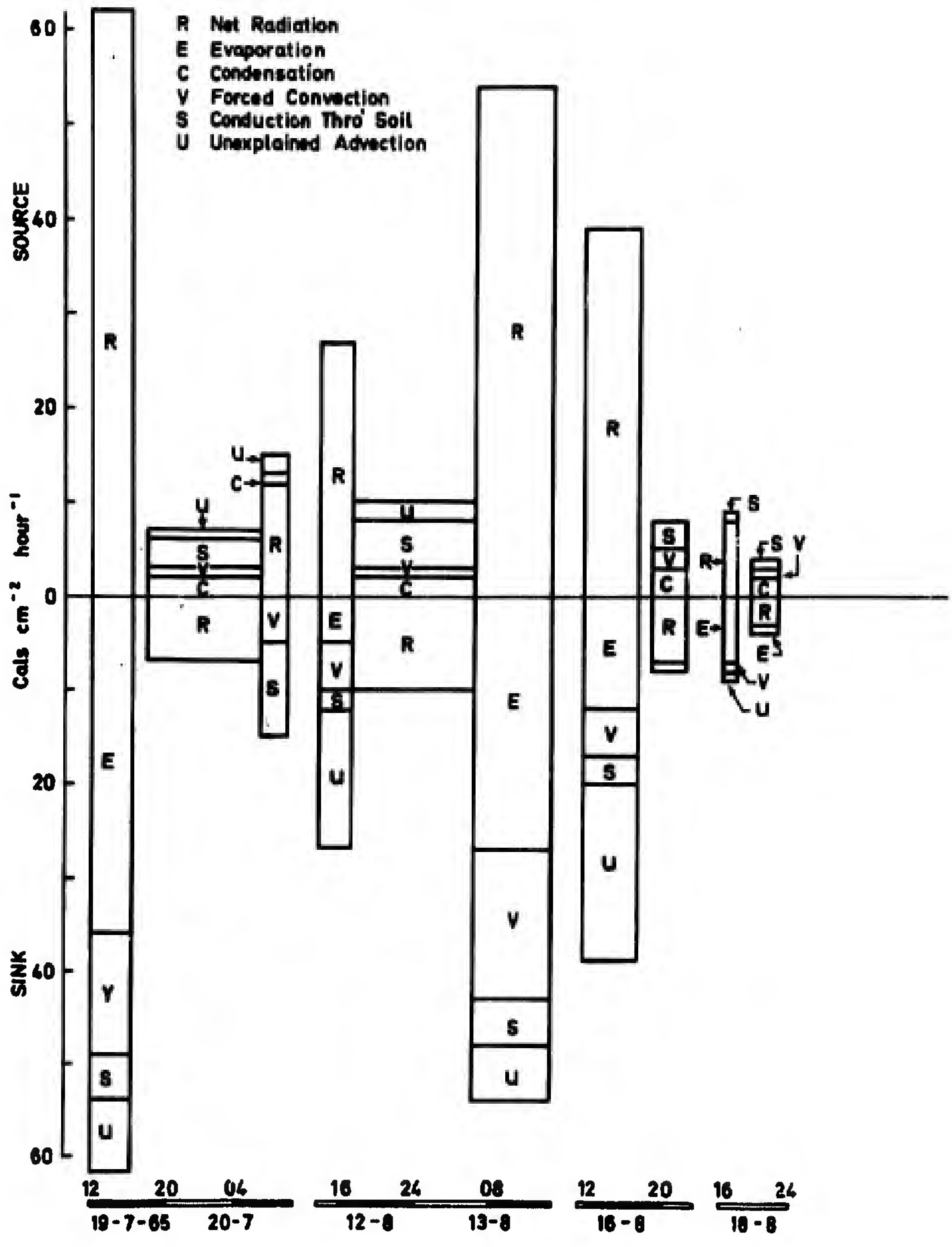

Fig.1.12. Heat balance at surface of Base Camp Meadow 4200m in Samir Valley.

METEOROLOGY REPORT I

Micro-Meteorology in the Samir Valley (4,200m)

by H. Gillman, H. Lister, and D.E. Prior

Summary

The problems of micro-meteorology work are outlined and a heat budget summarised for the surface of a short grass-covered, mountain basin at 4,200m. in the Samir Valley.

Introduction

The aim of the micro meteorology programme was:

1. To assess the source and sink of heat available at the surface of one glacier, the meltwater from which maintained a potentially useful river during the dry summer - See reports on Heat and Mass Balance of the Mir Samir Glacier.
2. To assess the heat and water vapour transfer through a 2m air layer above the surface of a high valley basin, typical of areas that are increasingly sought by villagers to supplement their fragmented holdings, adjacent to the villages in the main valleys. This work is summarised below.
3. To investigate the mechanism of momentum, heat and water vapour transfer over surfades having a wide range of air stability - See report on Air. Turbulence near the ground.

Not all these aims were achieved: Much of the apparatus was dependent upon a 12 volt supply, the small generator for which gave endless trouble until replaced by a larger unit eventually brought from the Hydrological Mission in Kabul who kindly lent it to the expedition. The intended period of observations was thus curtailed. To record simultaneously 30 variable elements in the heat flow mechanism, using apparatus designed for carrying in small units by man or horse, demanded extreme care, great patience and full co-operation of the 12 members of the expedition. All this was willingly given but inevitably, difficulties in checking, in correction and in maintaining equipment resulted in more than half the data being invalid. Values from a simple met. record are shown in the report on Glacier Heat Balance.

Vertical profiles of wind speed, temperature and vapour pressure to 2m, soil temperature to 30cm, gross and net radiation were measured over a coarse-silt floored basin with steep walls near the head of the Samir River. The apparatus and method was the same as described in the report on heat balance at the glacier surface. Soil pots 10 cm. dia. X 10cm deep were cut into the ground and weighed at 4 hourly intervals.

Measured evaporation reached a peak of 0.04 gm. cm.$^{-2}$ hr^{-1} but was generally less that $^1/_{10}$ of the calculated evaporation. The reasons seem to be : (i) Disturbance of the soil, rapid drying and difficulty in cleaning the outside of the pots before weighing; (ii) the calculated evaporation flux was representative of a wider range of soil surface than that sampled by the pots. Up wind of the apparatus, surface topography was very gently sloping with occasional shallow depressions. The short grass cover was more closely set in some of the hollows and near the river that meandered across the basin.

The heat balance calculated shows that the total heat available was rarely fully used: Advection is postulated since profiles of air temperature and vapour pressure showed marked anomalies near the surface. These could sometimes be traced from one test to the next, waxing and waning, but could not be correlated with any measured factor. Two horizontally spaced and simultaneously run stations would have helped considerably.

	Source	Sink
Day	Radiation 100%	Evaporation 44%
(27½ hours		Convection 23%
observed)		Advection 23%
		Soil heating 10%
Night		
(35½ hours	Heat from soil 42%	
observed)	Condensation 27%	Radiation 98%
	Advection 18%	Evaporation 2%

The relative importance of meteorological elements in the surface heat mechanism is shown in the table as a percentage and in figure 12 as calories cm^{-2} $hour^{-1}$. Though evaporation used nearly half the available heat through the day, the evaporated mass is small because of the high latent heat. With more readily available moisture in the ground, evaporation could be expected almost to double.

Results are grouped into day and night periods from the 30 minute test runs since wind speeds were low most of the time and hence turbulent transfer was very varied. The coefficients of this transfer (again, summarised in the report on heat balance at the glacier surface) were used here as for a neutral atmosphere with wind speed unaffected by temperature gradients. Adjustment of scales permitted the super-imposing of some temperature profiles but goodness of fit was rarely complete and for the vapour pressure profiles was frequently impossible. Similarly, vertical wind profiles could generally be fitted by a logarithmic law but temperature and vapour pressure profiles were far less amenable to this over the whole 2m.

Gradients of vertical profiles of temperature and wind speed, used as a ratio, give an index of air stability. Plotting such gradients is always imprecise and here, with low winds dominant, can only be bery approximate. Yet a criterion for division of the turbulence mechanism into categories of stability is essential. The first analysis of turbulence as part of this micro meteorology is outlined in the report on Air Turbulence near the ground.

METEOROLOGY REPORT II

The Climate of Afghanistan

by H. Lister

Summary

Climatic mean values are summarised systematically and a classification given on the basis of Köppen and of Thornthwaite. Temperature and Precipitation data are given and the calculated evapotranspiration compared with precipitation.

Position and Relief

The plateau of South West Asia extends from Iran into Afghanistan across an inland drainage basin below 500m. and rises with increasing gradient and range of relief to above 6000m. in the north east. From this junction in the north east with Russia and Pakistan at the mountain knot of the Pamirs and the Karakoram, the Hindu Kush Range swings south west and is continued by the Kok i Baba Mountains dividing the eastern half of the country. More than half the area is above 2000m. and has long ridges that reach Alpine Peaks and separate,deeply entrenched valleys in the East, but steeply flank wide valleys and broad plains in the South and West with only intermittent rivers between arid steppes and semi-desert.

Lying between 29° and 38° North (with the Oxus river forming much of the boundary with Russia) and separated from the Arabian Sea to the South by nearly 5° of latitude across the Uplands of Baluchistan, the country of Afghanistan is truly continental. The inter-tropical covergence lies immediately to the south of Afghanistan in summer giving tropical continental air masses over these countries. It is too far west to benefit from the South West Monsoon in summer and too far east to receive much rain (save in the high mountains) from the cyclones that cross from the Mediterranean in winter.

Met. Stations

This beautiful, mountainous, though sem-arid country is 250,000 square miles (ca. three times the size of Great Britain, or slightly larger than Texas) and has a population of 12 million. The eighteen principal met. stations thus provide a sparse cover from which to interpret climate, particularly since almost all of these stations have records for less than twenty years. HUMLUM (1959) in his excellent book: La Geographie de l'Afghanistan, - also considered data from 14 stations in countries bordering Afghanistan, and by adding personal observation and the indications of vegetation, achieved very useful though approximate maps of January and July isotherms and annual isohyets, supplemented by located, columnar diagrams of rainfall to indicate seasonal distribution.

Pressure and Winds

The tropical continental air over the high plateau gives very low barometric pressures in summer, but winds, even foehn winds, are generally light. Steady strong, northerly winds can persist for the summer months in the west and south and are known as 'the winds of 100 days'. Wind direction is so constant in the North West quadrant that windmills are used in West Afghanistan for grinding corn. These have wood vanes on a vertical axis mounted in a mud brick housing with fixed vents for directing onto the blades, the wind from one set direction Fig. 2.1. Over the plains in summer, dust whorls are common, reaching a few hundred metres height and moving at 30 knots or more.

Temperature and Humidity

In accordance with increasing altitude of the country, temperatures decrease from south west to north east. The arid south west has average January temperatures a little above 5°C and July temperatures well above 30°C. The sub-tropical regime begins immediately to the north, so in the west and round to the north along the Oxus river, temperatures in winter are a few degrees lower than these values and decrease towards the centre and North East where at about 2000 m. the January values are a little below 0° and July values a little below 35°C. Population is very sparse above 3000 m. in the centre and north east of the country where average January temperatures range below -5°C and July temperatures go above 20°C.

The absolute range of temperature, particularly in the centre and north is very great and can reach 70°C whereas 50° is more representative of the extreme range in the south and west.

Humidity is low in summer with averages of R.H. a little above 30% though 20% is common in the south west. In winter, R.H. values reach above 70% but are generally below 60% in the south west.

Precipitation

Since Afghanistan is surrounded by dry regions the rainfall is light, ranging from less than 5 cm. in the South West to more than 40 cm. in the North East, but over the central plains and in the deep valleys, rainfall average is between 20 and 30 cm. As with all semi-arid regions, variability is great; the Indian monsoon makes occasional incursions from across West Pakistan; cyclonic storms from along the Mediterranean can bring rain even so far east (HANSEN in World Meteorological Organisation, private communication).

Most of the rain falls between December and May, the south and west having four to five summer months completely dry.

Snow falls over most of the country but doesn't stay long on the ground in the south and west, though in the highlands of the centre and north east snow patches can be seen much of the year below the regional snow line at 5000 m. About this height snowfall increases eastwards to more than 100 gm cm^{-1} in the Hindu Kush mountains of Nuristan. Melt waters from these mountains supply the large deeply entrenched rivers that drain southwards to join the tributaries of the Indus, or in shorter streams drain north to the Oxus or to inland drainage further West.

Clear cloudless skies prevail but in late afternoon and at night a ground fog is possible due to radiational cooling. Some moisture could be collected from this by the new nylon thread combs but the amount would be very small.

<u>Classification of Climates</u>

Dry climates in which there is excess of evaporation over precipitation persist over all Afghanistan except in the mountains of the north east, so many rivers are intermittent and many are shrunken misfit streams for much of the year. Over this western half of the country the rainfall maximum in the early months of the year is at least three times the rainfall in the driest summer month which is near to zero. The ratio of the annual average temperature to the annual average rainfall is less than Köppens criterion for the boundary between arid desert and semi-arid steppe; thus the Köppen designation is B.Ws which has an added suffix h in the south West where the annual average temperature is above 18°C. Moving east the average temperature falls and rain increases so that the east and north half of the country becomes BSs, semi-arid steppe, the suffix h, because of altitude, not being so applicable as is generally shown on small scale maps of Köppen's climatic classification (Köppen 1936). The suffix s, summer drought, is applicable over the whole country.

In the highlands of the Hindu Kush, with temperatures in the coldest month below -3°C and snow cover persisting for months when precipitation is dominant, the Köppen designation becomes Ds, cold forest climate with a very few places such as North Salang where the warmest month is below 22°C, having the added b.

Thornthwaite's 1931 classification based on the Precititation/Evaporation ratio and the Temperature/Evaporation ratio or Thermal Efficiency index, gives DB's, semi-arid, mesothermal, rainfall scanti in summer for most of the country, but giving place to DCs, as the temperature falls into the microthermal bracket in the high eastern zone, where at successive heights a range of mountain climates is experienced.

Thornthwaite's 1948 classification indicates a western zone that is an extension into Afghanistan of the Persian desert, with Ed B'_4 meaning an arid climate with no water surplus and high in the mesothermal range of the thermal efficiency index. Further east and swinging along the northern border the lower temperatures and slightly increased rainfall gives a semi-arid climate with little water surplus but with a lower mesothermal letter: Dd B'_2. The central region is dry, sub humid with a light to moderate winter surplus of water and at the bottom of the mesothermal type: C_1 s B'_1. The zone at the east of the country and extending north becomes C_2, moist sub-humid and then B_1 sC' or humid, moderate winter water surplus and microthermal.

Availability of Water

The above extrapolations on climate are based upon data (listed in appendix) kindly supplied by Ali Mohamed Noor, Director of Climatology at the Afghan Air Authority, Ansary wat, Kabul. Mean monthly precipitation and temperature for the period of the records (which is rather short for climatic inference) is shown in figure 2.2. The dominance of winter precipitation with moderate and low temperatures and the nearly complete absence of precipitation during the hot summer are very evident. The marked increase of rainfall with altitude suggests the possibility of water storage in the mountains to supply the lower reaches during the dry summer.

Various expressions for calculation of evaporation have been tried. The best of these, that by PENMAN (1953) could not be applied to the limited data here available.

Figure 2.3. shows the data after being treated by the Thornthwaite system for calculation of potential evapotranspiration to find for each month of the year, the amount of water surplus or deficiency. In accordance with Thornthwaite, 10 g cm^{-2} has been allowed as the maximum possible soil moisture storage, but in the mountain regions particularly, this figure is probably too high, which means that the water deficiency estimates are too low. Furthermore, in the Sahara and in Central Australia, the measurement of evaporation by water pans indicated that in such regions the Thornthwaite expression, under estimated evaporation by a factor of 2 (SIBBONS 1962 p 284). Bearing in mind the probability of underestimating the evapotranspiration and hence the water deficiency, figure shows that there is a water surplus, lost as run off, during the first three to four months of the year over the north eastern half of the country, but north and east of Kabul the amount of this water surplus in spring nearly equals the water deficiency in summer.

The station record at Salang 3,100 metres altitude is the only one showing a large positive balance of precipitation over evaporation. This station may be considered representative of the many steep sided,high valleys with intermittent basins of terraced slopes and small flood plains almost isolated by sections of precipitous gorges.

The Panjshir river flows through such a steep sided valley system to disgorge onto the plains North of Kabul and flow east as a tributary of the Indus. The hydrograph reflects the spring flood and shows a moderate discharge maintained through the summer by the snow melt from the snow patches that blanket the mountains above 3,000 metres, receding during the summer to the snow line at 5,000 metres, where precipitation is approximately 100 gm cm^{-2}.

The increasing height of the snow line during the past few decades has left empty corrie basins and shrunken glaciers and will, if continued, seriously deplete the run off in middle and late summer. For the present, however, these mountain valleys have sufficient river water, the inhabitants basically requiring assistance in making distributary channels to put the water effectively over the available useful land. Gorges along the river valleys give opportunity for dams to retain water until higher temperatures in summer over the plains would give optimum vegetation response. Such a project is already being investigated by a hydrology team of the U.N.

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Climate data for Afghanistan

Station position, height and period of observations in years is given below with mean monthly temperatures °C and precipitation mm.

Jalallabad 19 yrs.
34-26 N 70-27 E 552 m

	°C	mm
Jan	8.6	18.8
Feb	11.1	17.9
Mar	17.2	32.9
Apr	22.4	23.6
May	27.9	12.9
Jun	32.4	1.1
Jul	32.9	5.1
Aug	31.9	2.8
Sep	28.8	3.1
Oct	22.8	1.9
Nov	15.5	8.1
Dec	9.0	15.3

Kabul airport 9 yrs.
37-33 N 69-12 E 1803 m

	°C	mm
Jan	2.8	26.3
Feb	0	53.5
Mar	6.7	71.5
Apr	11.9	104.7
May	16.7	33.9
Jun	20.3	1.5
Jul	24.7	6.9
Aug	23.9	1.7
Sep	20.7	0.1
Oct	12.7	1.2
Nov	5.1	22.1
Dec	0.3	30.6

Karizimir 6.5 yrs
37-40 N 69-05 E 1860 m

Jan	-3.3	37.4
Feb	-0.4	57.7
Mar	5.2	110.4
Apr	10.5	136.5
May	15.5	38.3
Jun	18.9	1.3
Jul	22.5	3.5
Aug	21.6	0.9
Sep	17.4	0.6
Oct	11.5	5.2
Nov	4.2	32.3
Dec	-0.1	32.6

Kunduz 7 yrs
36-32 N 68-53 E 430 m

Jan	2.3	46.7
Feb	5.6	52.0
Mar	11.3	52.5
Apr	16.5	85.4
May	22.1	44.1
Jun	28.8	1.3
Jul	31.5	4.0
Aug	29.0	0
Sep	23.8	Tr
Oct	16.1	6.0
Nov	8.0	23.2
Dec	3.6	39.3

Kandahar 21 yrs
31-37 N 65-48 E 1010 m

Jan	5.2	40.8
Feb	9.9	38.3
Mar	14.8	39.8
Apr	19.8	21.0
May	24.2	8.7
Jun	29.2	6.3
Jul	30.5	0.9
Aug	28.7	0
Sep	23.2	0
Oct	17.6	1.8
Nov	10.3	5.6
Dec	6.7	22.0

Khost 2.5 yrs
33-40 N 69-55 E 1185 m

Jan	3.6	8.7
Feb	8.4	24.5
Mar	12.9	73.6
Apr	17.1	72.4
May	22.5	56.7
Jun	28.1	16.3
Jul	27.5	126.2
Aug	26.5	82.6
Sep	23.0	50.3
Oct	17.7	7.1
Nov	10.2	3.2
Dec	5.6	5.1

Lashkarguh 15 yrs
31-30 N 64-28 E 780 m

Jan	5.2	11.5
Feb	10.3	14.6
Mar	15.9	31.2
Apr	20.5	11.6
May	26.2	6.8
Jun	30.6	0
Jul	32.2	0
Aug	30.5	0
Sep	24.4	0
Oct	17.0	0
Nov	10.6	1.1
Dec	5.9	16.4

Mazarisharifs 12 yrs
36-42 N 67-13 E 378 m

Jan	3.3	57.0
Feb	7.2	28.1
Mar	11.4	36.9
Apr	17.6	35.5
May	24.0	11.8
Jun	28.3	0.1
Jul	30.7	Tr
Aug	28.0	0
Sep	22.1	0.3
Oct	15.3	2.8
Nov	6.9	18.0
Dec	4.5	22.9

Maimana 12 yrs
35-55 N 64-44 E 858 m

Jan	3.5	49.4
Feb	6.1	55.4
Mar	8.8	93.7
Apr	14.4	60.4
May	19.6	41.0
Jun	24.4	3.1
Jul	26.6	0.1
Aug	24.9	Tr
Sep	20.0	0.1
Oct	13.9	6.3
Nov	7.9	29.4
Dec	3.9	33.0

North Salang 5 yrs
35-22 N 69-03 E 3100 m

Jan	-10.5	103.6
Feb	-8.3	140.8
Mar	-4.1	237.1
Apr	-0.3	241.6
May	3.7	163.3
Jun	8.3	8.5
Jul	11.2	5.4
Aug	8.2	1.5
Sep	4.2	6.9
Oct	0.3	12.9
Nov	-4.3	101.5
Dec	-7.7	102.1

Shebirghan 2 yrs
40 N 65-43 E 360 m

Jan	2.7	40.3
Feb	6.2	5.6
Mar	12.2	26.3
Apr	15.2	26.4
May	21.7	Tr
Jun	29.3	0
Jul	31.0	0
Aug	26.8	0
Sep	22.5	0
Oct	15.0	1.5
Nov	10.0	11.1
Dec	1.3	25.2

Gerdiz 13 yrs
33-47 N 69-17 E 2503 m

Jan	-5.5	34.5
Feb	-3.1	55.3
Mar	4.1	61.5
Apr	9.9	38.3
May	15.1	26.0
Jun	19.6	6.0
Jul	22.7	14.2
Aug	22.6	6.8
Sep	17.0	1.2
Oct	9.4	5.6
Nov	4.4	8.8
Dec	-1.8	35.5

Baghlan 12 yrs
36-12 N 68-12 E 510 m

Jan	2.5	25.6
Feb	6.5	39.7
Mar	9.5	52.0
Apr	15.6	59.8
May	21.3	16.1
Jun	25.8	0.1
Jul	28.0	0.3
Aug	25.4	0.3
Sep	20.1	0.1
Oct	14.1	2.8
Nov	6.4	29.5
Dec	3.4	22.7

Farah 15 yrs
32-24 N 62-07 E 651 m

Jan	6.0	14.0
Feb	8.3	20.4
Mar	16.0	12.8
Apr	15.5	9.7
May	25.4	2.7
Jun	31.0	Tr
Jul	33.7	0
Aug	31.4	0
Sep	25.8	0
Oct	19.0	0
Nov	10.6	2.6
Dec	6.9	10.5

Faizabad 1.5 yrs
37-09 N 70-29 E 1200 m

Jan	-4.6	20.1
Feb	2.5	110.9
Mar	9.2	108.0
Apr	12.8	151.0
May	16.3	38.0
Jun	4.2	4.0
Jul	25.4	7.4
Aug	24.9	0
Sep	19.6	5.0
Oct	13.6	2.4
Nov	7.8	30.6
Dec	1.0	21.0

Chazni 16 yrs
33-32 N 68-25 E 2183 m

Jan	-6.3	38.2
Feb	-2.3	45.6
Mar	4.4	80.0
Apr	9.0	56.0
May	16.0	29.0
Jun	21.0	2.4
Jul	23.0	13.0
Aug	22.0	1.0
Sep	20.0	0.6
Oct	16.0	0.1
Nov	8.0	11.5
Dec	5.0	23.0

Herat 19 yrs
37-11 N 62-13 E 964 m

Jan	5.0	44.1
Feb	7.6	34.7
Mar	10.5	52.9
Apr	16.3	22.5
May	22.3	8.5
Jun	26.1	0.3
Jul	29.1	0.8
Aug	28.0	0
Sep	23.0	0.1
Oct	14.9	0.1
Nov	7.8	10.2
Dec	4.0	30.8

Jabal Garaje 4 yrs
35-08 N 69-15 E

Jan	0.5	35.7
Feb	5.0	79.8
Mar	10.0	91.6
Apr	13.7	113.5
May	19.9	53.8
Jun	24.7	0.9
Jul	27.3	3.9
Aug	26.4	0.1
Sep	22.8	1.2
Oct	17.3	3.6
Nov	9.5	39.8
Dec	4.0	37.0

METEOROLOGY REPORT III

Turbulence near the Ground

by H. Lister, A. Pendlington and D. E. Prior

SUMMARY

In this investigation, a continuous photographic analogue was made of wind velocity, inclination and declination over brief time intervals above the short sparse grass surface of a nearly flat, silt floor of a steep-walled mountain basin at 4,200m (13,800 ft) in N.E. Afghanistan. The trace records of the calibrated hot wire anenometers, recorded by a miniaturised multi-channel galvanometer, were subsequently digitised producing a paper tape having punched holes arranged in code, giving the displacement of each point digitised. A computer programme was devised which treated each punched-tape trace analogue separately, producing auto correlation diagrams, power spectrum curves and data on the energy of the fluctuating quantities. The three traces were then combined to produce for each moment of time actual velocities in cm sec^{-1} for the vertical, horizontal and lateral directions of the turbulent air field, as defined by a vector model. Autocorrelograms and power spectra of these vector components were then produced and values of energy and shear stress at each height calculated. These with the position and shape of the peaks in the power spectrum and rate of fall off in auto-correlation were compared at different heights and air stabilities.

INTRODUCTION

Transfer of momentun, heat and water vapour by eddying air is a fundamental process in the hydrological cycle yet is little understood. Eddies are difficult to define and describe in terms of physical models and dimensions. Eddies cannot be assigned sizes or points in time as though assuming some discrete form, but as in the case of the electron, eddies may be considered random disturbances, which on average, exhibit certain measurable tendencies. The size of an eddy then emerges as the wave length of a disturbance propagated through the air flow; the periodicity of the pattern of disturbance is shown as a peak in auto-correlation diagrams. Spectral distributions based upon covariance estimates, when combined with an adapted form of Fourier analysis demonstrate the proportion of the available energy associated with disturbances, covering a selected vanishingly small frequency range.

Some basic theory of turbulent air flow

Reynolds recognised that turbulent flow may be divided into a mean velocity $\bar{u}$ and a superimposed eddy velocity u'. The instantaneous velocity is the sum of these. Using x, y and z axes for horizontal, transverse, and vertical velocity components u, v and w, Reynolds showed that the effect of the fluid boundary resulted in a shearing stress τ. With ρ = fluid density

$$\tau = -\rho \overline{u'w'} \qquad 1.$$

which expresses the vertical transfer of momentum by the eddy velocities.

Initially it may be assumed (Sutton 1953, p. 68) that the rate of transfer of any conserved property in the flow is proportional to the gradient of its mean flow. The factor of proportionality is regarded as an exchange coefficient (Austauschkoeffizient).

Prandtl introduced a mixing length l which characterises the local intensity of turbulent mixing (Sutton 1953, p. 73). The turbulent exchange coefficient K is $w'l$ and if l is defined as the distance a parcel of air moves in the turbulent stream before it changes its initial characteristics

$$u' = l \frac{d\bar{u}}{dz} \qquad 2$$

If the turbulent motion is uniform, the components may be considered equal

$$\bar{u}' = \bar{v}' = \bar{w}' = 0 \qquad 3$$

and hence from 1 and 2

$$\tau = -\rho\, l^2 \left(\frac{du}{dz}\right)^2 \qquad 4$$

is considered constant in the first few metres of height. Prandtl suggested that l could be expected to increase as the distance from the fluid boundary increased. If k is von Karman's constant of proportionality ($\simeq$ 0.4) and z the distance from the boundary,

then $$l = kz \qquad 5$$

therefore $$\frac{du}{dz} = \frac{1}{kz}\sqrt{\frac{\tau}{\rho}} \qquad 6$$

which, on integrating between two levels yields

$$u_2 - u_1 = \frac{1}{k}\sqrt{\frac{\tau}{\rho}}\ \ln\left(\frac{z_2}{z_1}\right) \qquad 7$$

Because of surface roughness the wind speed falls to zero at some height above an absolute datum. This height is termed z_0, the coefficient of surface roughness. $\left(\sqrt{\frac{\tau}{\rho}}\right)$ has dimensions of velocity and is termed the shear velocity u_*. The general law of wind speed variation with height is

$$u_z = \frac{u_*}{k}\ \ln\left(\frac{z}{z_0}\right) \qquad 8$$

Fluid density is separated from the turbulent exchange coefficient giving Km the coefficient of eddy viscosity.

$$\tau = \rho\, K_M \left(\frac{du}{dz}\right) \qquad 9$$

From 5 and 7, Km at a particular height can be expressed

$$K_M = \frac{k^2 z u_z}{\ln\left(\frac{z}{z_0}\right)} \qquad 10$$

If the fluid has a marked temperature gradient some particular entities may have a different mixing length and the more buoyant, warmer elements may have a different vertical motion w'. Yet, because of the difficulty of finding the turbulence coefficients of heat K_H and of vapour transfer K_V it is generally assumed that

$$K_M = K_H = K_V \qquad 11$$

A heated surface can be expected to encourage turbulence and conversely a cold surface to suppress turbulence. In such conditions wind speed variation with height departs from the logarithmic law (8) but no universal law is yet widely accepted (Grainger & Lister 1965). The law (8) fits an extensive range of data in an adiabatic atmosphere. Departure from such a neutral atmosphere is indicated by a stability index such as Richarson number R_i which expresses as a ratio the buoyancy forces to the inertia forces when a parcel of air moves through a distance l

$$Ri = \frac{g}{T} \frac{\frac{dT}{dz} + \Gamma}{\left(\frac{du}{dz}\right)^2} \qquad 12$$

g = force due to gravity

T = mean temperature in ^oK

Γ = adiabatic lapse rate = 1×10^{-4} ^oC cm^{-1} which generally can be neglected in comparison with $\left(\frac{dT}{dz}\right)$ in the lowest few metres of atmosphere.

The dimensionless number Ri is positive for stable, negative for unstable and zero for neutral (adiabatic) atmosphere.

Richardson also assumed identity of K_H and K_M. If this is not the case, then the flux form of Richardson number Rf should be used

$$Rf = \left(\frac{K_H}{K_M}\right) Ri \qquad 13$$

This is difficult to obtain without actual flux measurements so (12) is generally applied. Turbulent motion breaks down and subsides into laminar motion at a critical stability, values for which range between 1 and 0.14 (McVehil 1964, p. 136).

Thus for study of air turbulence over a specific site, a continuous record is required of the fluctuations in temperature, vapour pressure and the three components of wind speed, accompanied by their mean gradients over the period of observation.

Vector model of turbulence components

In figure 2.4 the reference axes are a cartesian system arranged so that for the period of sampling the x axis lies along $\underline{OC}$ the direction of the mean wind vector $\underline{\overline{W}}$. The relation between the mean and the instantaneous wind $\underline{W}$ shown along OJ is

$$\underline{W} = \underline{\overline{W}} + \underline{W}' \qquad 14$$

the dash indicates a quantity deviating from the mean value. The direction $\underline{OC}$ is defined with respect to the orthogonal axis fixed in the sensing head of the apparatus and with Ox directed along the long axis of the head by angles $\overline{\Theta}$ and $\overline{\Psi}$ where

$$\overline{\Theta} = \tan^{-1}\left[\frac{\sum_{i=1}^{N} W_i \sin\Theta_i}{\sum_{i=1}^{N} W_i \cos\Theta_i}\right] \qquad 15$$

$$\overline{\Psi} = \tan^{-1}\left[\frac{\sum_{i=1}^{N} W_i \cos(\Theta_i - \overline{\Theta}) \sin\Psi_i}{\sum_{i=1}^{N} W_i \cos(\Theta_i - \overline{\Theta}) \cos\Psi_i}\right] \qquad 16$$

Θ = angle of inclination and Ψ = angle of declination of the instantaneous wind.

N = total number of data points in sampling period.

The wind components are shown in the upper diagram of figure 2.4 with orientation relative to the horizontally mounted apparatus. The vectors shown as heavy lines can now be rotated, with their axes, to the more simple form shown in the lower diagram of figure 2.4.

The arrangement in the figure of the reference axes Oxyz satisfies the condition that over the period of sampling, the algebraic sum of the mean deviations from the mean wind $\underline{W}$ is zero.

$$\overline{u'} = \overline{w'} = \overline{v'} = 0 \qquad 17$$

and

$$\overline{v} = \overline{w} = 0 \qquad 18$$

the componenst of the vector wind, referred to axes oxyz are then

$$\left.\begin{array}{ll} \text{along Ox} & u' = W\cos(\Theta-\overline{\Theta})\cos(\Psi-\overline{\Psi}) \\ \text{along Oy} & v' = W\cos(\Theta-\overline{\Theta})\sin(\Psi-\overline{\Psi}) \\ \text{along Oz} & w' = W\sin(\Theta-\overline{\Theta}) \end{array}\right\} \qquad 19$$

The eddy velocity components u, v, w are then defined

$$u' = u - \bar{u}$$
$$v' = v \qquad\qquad 20$$
$$w' = w$$

where $\bar{u} = \frac{1}{N}\sum_{i=1}^{N} u_i = \bar{W}$

The components of turbulence are now:

$$u' = W \cos(\theta-\bar{\theta})\cos(\psi-\bar{\psi}) - \frac{1}{N}\sum_{i=1}^{N} W_i \cos(\theta_i-\bar{\theta})\cos(\psi_i-\bar{\psi})$$

$$v' = W \cos(\theta-\bar{\theta})\sin(\psi-\bar{\psi}) \qquad\qquad 21$$

$$w' = W \sin(\theta-\bar{\theta})$$

The above model assumes continuous measurement of wind velocity and its inclination θ and declination ψ but these variables are measured by three separate probes (figure 2.5) with 5 cm. horizontal distance between each. Furthermore, each probe head has dimensions with width up to 2 cm. Hence the measurements are not taken at a point in space; the air affecting one probe is not necessarily identical with the air passing over the adjacent probe.

To illustrate this by an oversimplification we may assume that the empirical relationship between wavelength λ, frequency n and velocity v of simple sinusoidal form can be applied to the generation of periodic patterns of turbulent eddies in an air layer. The expected wavelength and hence the expected size of eddies present may be estimated for a given air speed and required frequency. e.g. an airstream flowing at 2 m sec^{-1} with frequency 10 c.p.s. should have a probable wavelength, found from:

$$v = n$$
$$2 = 10$$
$$\lambda = 0.2 \text{ m}$$

Such an eddy size of 20 cm. passing over the measuring probes should give values to fit the above model. For a wavelength equal to the 10 cm. between the outer probes, an air speed of 1 m sec^{-1} gives a generation periodicity of 10 c.p.s. or for an air speed of 2 m sec^{-1} a periodicity of 20 c.p.s. If the output from all three probes must be in response to eddies that envelope the whole probe assembly, i.e. eddies > 10 cm., then the frequency of examinable patterns from this assembly is dependent upon the average wind speed. At 0.5 m sec^{-1} this max, frequency is 5 c.p.s.; at 5 m sec^{-1} it is 50 c.p.s. However, such oversimplification suggesting discrete swirls or parcels of air is improbable.

TIME SERIES ANALYSIS

Methods for searching for 'hidden periodicities' in time series were postulated in the late eighteenth and early nineteenth century by such mathematicians as Lagrange and Buys-Ballot but the most famous method was that devised by Sir Arthur Schuster in 1898-1906 which gave rise to the Shuster periodogram - a function of the form:-

$$F(n) = \frac{1}{N}\left[\left(\sum_{i=1}^{N} x_i \cos ni\right)^2 + \left(\sum_{i=1}^{N} x_i \sin ni\right)^2\right]$$

n = frequency, N an integer dependent upon the length of the series. This function has peaks corresponding to the period of some repetitive pattern existing in the series.

In nearly all the methods of analysis the time series X_{ti}, say, (i = 1, 2, 3 .... N), was considered to be one compounded of some periodic function representable by a cosine series, a random irregular function E_t and a slow trend which affected the mean behaviour of the whole series. This general type is termed the linear cyclic model. The purpose of the analyses was to separate the periodic function from both the irregularities and the slow trends.

The periodogram method, however, turned out to be unreliable in that it showed peaks occurring in the spectrum corresponding to frequencies which were definitely known not to be present in the original series. This drawback led researchers such as Yule and Kendal (Kendal. and Yule 1946 p. 497) to search for other possible models for revealing cyclical phenomena in time series. Yule in particular noted that many naturally occurring time series could be represented by either of the equations:-

$$X_t = \sum_{i=0}^{N} \left(a_i \epsilon_{(t-i)}\right)$$

$$\text{or} \quad X_t + \sum_{i=1}^{N} \left(a_i X_{(t-i)}\right) = \epsilon_t$$

The first equation is termed a moving average process and the second generalises an autoregressive process. The solutions of such equations as these have been pursued by Wold (Stationary Time Series Stockholm 1938 (2nd Edn. 1958)) and Durbin (Efficient Estimation of Parameters in Moving Average Models. Biometrika Vol. 46 (1959) pp. 306-316), (Estimation of Parameters in Time-Series regression models. Journal Royal Stat. Soc. (B) Vol. 22 (1960) pp. 139-153.)

These three models, the linear cyclic, the moving average and the autoregressive, were considered, up to about 1940, to be the only possible alternatives in analysing time series. However, using the rapid developments in the theory of probability and statistics and applying these to the essentially Fourier based methods of analysis of Norbert Wiener, etc. Tukey and Blackman (1958) of the Bell Telephone Laboratories developed a powerful tool in analysing time series which is less dependent on the assumption of a definite physical model underlying the theory than was previously required. These modern techniques rely upon the development of a statistical distribution function, the job of which is to modify and shape some total function indigenous to the problem (such as the total available power) to suit the requirements demanded by the observed data and/or situations. They basically adopt the Fourier method of analysis but are more realistic in that the discontinuous nature of the periodograms is taken into account, the extremes of the frequency ranges automatically limited, smoothing of the final spectral estimates is performed to obtain the average energy over small finite frequency bands, and methods of eliminating error sources such as 'aliasing' etc. are incorporated. In addition it is easy using tables of the chi-square distribution to place statistical limits of significance upon the results using this method.

Semi-rigorous development of theory of time series analysis

Suppose X_i ($i = 1, 2, 3 \ldots\ldots N$) is a stationary (i.e. the results are unaffected by shifting the time origin) Gaussian normal time series. Such a series is completely characterised by three quantities:-

(1) The AVERAGE:-

$$\bar{X} = \frac{1}{N} \sum_{i=1}^{N} X_i$$

(2) The AUTOCOVARIANCE series:-

$$C(\tau) = \frac{1}{N-\tau} \sum_{i=1}^{N} (X_i - \bar{X})(X_{(i+\tau)} - \bar{X})$$

(3) The VARIANCE:-

$$\sigma^2 = C(0) = \frac{1}{N} \sum_{i=1}^{N} (X_i - \bar{X})^2$$

The autocovariance function is often called the autocorrelation function but this term is usually only applied to the normalised quantity (C( )/C(0)).

Suppose now the series is complex with zero mean. The three quantities needed to describe completely this series are then (cf. GRANGER 1964 p. 27 et seq)

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i = 0 \qquad 22$$

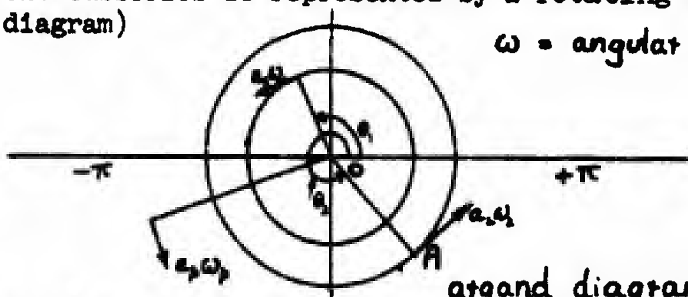
$$C(\tau) = \frac{1}{N-\tau}\sum_{i=1}^{N-\tau} X_i \bar{X}_{(i-\tau)} \qquad 23$$

$$\sigma^2 = C(0) = \frac{1}{N}\sum_{i=1}^{N} X_i \bar{X}_i \qquad 24$$

where $\bar{X}_i$ is the complex conjugate of X_i.

By use of the complex quantities the cyclical nature of the subseries contributing to the whole may be conveniently described in cis θ form.

Let each component subseries be represented by a rotating vector similar to OA (argand diagram)



cis θ is the shortened notation for the complex quantity $\underline{a} = |\underline{a}|(\cos\theta + j\sin\theta)$ where $j = \sqrt{-1}$ (see Argard diagram). Also $(\cos\theta + j\sin\theta) = e^{j\theta}$

OA has a magnitude:-

$$\underline{a}_1 = |\underline{a}_1|(\cos\theta_1 = j\sin\theta_1)$$

and in general the magnitude of the p^{th} vector is:-

$$\underline{a}_p = |\underline{a}_p|(\cos\theta_p + j\sin\theta_p)$$
$$= \underline{a}_p\, e^{j}\, p$$

Then the series X_i may be represented by the sequence of sums in which the i^{th} point of the N data is given by

$$X_i = \sum_{p=1}^{q} |\underline{a}_{pi}|\, e^{j\theta_{pi}} \quad \text{for } i = 1, 2, 3 \ldots. N$$

since $\theta_{pi} = \omega_p t_i$ where t is the time interval between data points of the series then

$$X_i = \sum_{p=1}^{q} |\underline{a}_{pi}|\, e^{j\omega_p t_i} \quad i = 1, 2, 3 \ldots. N$$

Hence from 23

$$C(\tau) = \frac{1}{N-\tau}\sum_{i=1}^{N-\tau}\sum_{p=1}^{q} |\underline{a}_{pi}|(\cos\omega_p t_i + j\sin\omega_p t_i)\sum_{p=1}^{q}\underline{a}_{pi}\,(\cos\omega_p t_{(i-\tau)}$$

$$- j\sin\omega_p t_{(i-\tau)})$$

$$= \frac{1}{N-\tau} \sum_{i=1}^{N-\tau} \sum_{p=1}^{q} \left|a_{p_i}\right|^2 (\cos\omega_p t_i \cos\omega_p t_{(i-\tau)} + \sin\omega_p t_i \sin\omega_p t_{(i-\tau)}$$

$$+ j (\sin\omega_p t_i \cos\omega_p t_{(i-\tau)} - \cos\omega_p t_i \sin\omega_p t_{(i-\tau)})$$

$$= \sum_{p=1}^{q} \left|a_p\right|^2 (\cos\omega_p(t_i - t_{(i-\tau)}) + j \sin\omega_p(t_i - t_{(i-\tau)}))*$$

$$\therefore C(\tau) = \sum_{p=1}^{q} \left|a_p\right|^2 e^{j\omega_p}$$

But $\left|a_p\right|^2$ is the square of the amplitude of the disturbance having an angular frequency of ω_p, i.e. a measure of the variance, or power, of that particular frequency at that lag-time. To bring this out more clearly we may write (cf. Granger 1964, p. 28) σ_p^2 for $\left|a_p\right|^2$ and hence:-

$$C(\tau) = \sum_{p=1}^{q} (\sigma_p)^2 e^{j\omega_p}$$

or since $\omega = \frac{2\pi}{n}$ where n = frequency in cps

$$C(\tau) = \sum_{p=1}^{q} \sigma_p^2 e^{(2\pi j/n_p)} \qquad 25$$

* cos A cos B + sin A sin B = cos (A - B)
sin A cos B - cos A sin B = sin (A - B)

25 may be written in the following form:-

$$C(\tau) = \sum_{p=1}^{q} e^{\left(\frac{2\pi j}{n_p}\right)} F'(n)\Delta n$$

where $F'(n)\Delta n = \sigma_p^2$ and is a function whose distribution describes the nature of the spread of the total variance of the series among the frequency bands of width Δn centred on n_p.

If we now suppose the series to be built up from an infinite number of such vectors as has been described such that each point on the $(\pi, -\pi)$ axis contributes, then the distribution may be regarded as continuous and the summation replaced by an integral sign. Hence for a continuous frequency distribution (i.e. resulting in a spectrum that has no lines) JENKINS, 1961, p. 136 et seq.):-

$$C(\tau) = \int_0^\infty e^{\left(\frac{2\pi j}{n}\right)} F'(n)\,dn \qquad 26$$

where F'(n)dn represents the variance contribution from frequencies between n - dn and n + dn at lag .

From 26:-

$$C(0) = \int_0^\infty e^0 F'(n)dn = \int_0^\infty F'(n)dn$$

but from24 $C(0) = \sigma^2$

$$F'(n)dn = \sigma^2$$

0

If $F(n) = \frac{F'(n)}{2}$

then $$\int_0^\infty F(n)dn = 1 \qquad 27$$

27 can be seen to be the parallel of the probability density function ψ of wave mechanics in which the fact that the probability of locating a specific electron somewhere in the universe is unity (i.e. certain) is expressed by

$$\int_0^\infty \psi\psi^* = 1$$

The above exposition attempts crudely to establish an idea of the meaning of the F(n) function used in plotting energy spectra. It is not rigorous and is not intended so to be, for this, reference must be made to the numerous works listed in connection with the analysis of time series. Thus it is stated here without proof that the link between F(n) and $C(\tau)$ which permits the calculation of F(n) from a knowledge of the autocovariance series of a given sequence of data is that F(n) and $C(\tau)$ are Fourier transforms of one another (Blackman and Tukey 1958 p. 84. Taylor 1960 p. 454), i.e.

$$F(n) = \int_0^\infty \frac{C(\tau)}{\sigma^2} \cos\left(\frac{2\pi}{n}\right) dn$$

The method in which the practical analysis of the data, resulting in the curves discussed at the end of this section, was carried out and which now follows is based on that summarised by Jones 1957 from the development of the theory by Tukey and Blackman 1958.

First from the series of dat. is obtained the autocorrelogram (normalised) corresponding to the series of ratios $(C(\tau)/C(0))$, expressions 23 and 24.

Correlation of any series of values with those same values obviously gives a coefficient of unity. The series of values, equally spaced in time, is then moved along one space and the correlation repeated. This process is repeated to find where the correlation coefficient falls to near zero and a plot of these successive values is the normalised autocorrelogram.

The equation used to generate the autocorrelogram is

$$R(k) = \frac{\sum_{i=1}^{N-k} (X'_i)(X'_{(i+k)})}{\sqrt{\sum_{i=1}^{N-k} (X'_i) \sum_{i=1}^{N-k} (X'_{(i+k)})}} \qquad k = 0, 1, 2 \ldots . r \qquad 28$$

where k is the correlation interval in data points
and r is the truncation length or the point in the series where auto-correlation is terminated. Here an r value giving approxiamtely 15% of trace length has been used for each single observation.
X represents the instantaneous value of the parameters u, v or w.

$$\text{and} \qquad X' = X - \frac{1}{T} \int_{-T/2}^{+T/2} dt \qquad 29$$

In the analysis, the integral becomes the arithmetic mean over the time interval T centred on time T/2 and hence is computed from

$$\frac{1}{N} \sum_{i=1}^{i=N} X_i \qquad 30$$

in which $X_i = u_i, v_i$ or w_i

the velocity, declination or inclination of the air stream and N = total number of data points in the sampling period. (cf. expression 22).

Bendat and Piersol (1966, pp. 288-290) have conveniently listed equations from which having decided upon the standard error required and the maximum frequency to be observed, the experimenter may compute the minimum trace length and data sample size needed to conform to such statistical limits. These equations are:-

(i) Sampling interval δt.

δt is the time between sampling of data points and is chosen so that

$$\delta t = \frac{1}{2n^1_{cps}} \qquad (31)$$

where n^1 is the upper frequency limit in the range investigated.

(ii) Number of corrleation lag values m

The maximum value of m must be such that for a desired equivalent resolution bandwidth B_e

$$m = \frac{1}{\delta t \; B_e} \qquad (32)$$

(iii) Sample size N and record length T

N and T are linked to ϵ_e the normalized standard error decided upon to apply to the spectral estimates and to the degrees of freedom f_d by the following relations

$$N = \frac{m}{\epsilon_e^2} \qquad (33)$$

From which the minimum record length T is then given by $T = N.\delta t$.

f_d and ϵ_e are connected by the formulae

$$f_d = 2.\,B_e\,T = \frac{2N}{m} \qquad (34)$$

$$\epsilon_e = \frac{m}{N} \qquad (35)$$

An alternative formula used for large m is

$$f_d = 2\left(\frac{N - m/4}{m}\right) \qquad (36)$$

which for small m approximates to (34).

Various workers suggest that to obtain statistically the highest accuracy, $f_d > 30$ and $6 < m < 30$.

In the estimation of the spectra, the centres of the particular frequency bands examined are defined in number and width by the values of m and δt. respectively through the equation:-

$$n_{cps} = \left(\frac{1}{2m\,\delta t.}\right) . k \qquad k = 0, 1, 2 \ldots\ldots m \qquad (37)$$

The energy spectrum for each trace is found by first forming the covariance value Q_k for the (m + 1) time lags.

$$Q_k = \frac{1}{N-k}\left[\sum_{i=1}^{N-k} X_i X_{(i+k)} - \frac{1}{N-k}\sum_{i=1}^{N-k} X_i \sum_{i=1}^{N-k} X_{(i+k)}\right] \qquad (38)$$

The following Fourier transform is then applied to those lagged covariance values giving the raw spectral estimates

$$L_j = \frac{1}{2\pi}\left[Q_o + 2\sum_{k=1}^{m-1} Q_k \cos\left(\frac{\pi kj}{m}\right) + Q_m \cos(\pi j)\right] \qquad (39)$$

$j = 1, 2, 3 \ldots\ldots (m-1)$

where $\sum_{j=0}^{m} L_j = Q_o$ the total variance of the series.

The quantity F(n) Sn (cf. expressions 26 and 27) the contribution to the total variance by a frequency band of width δn is related to the L_j's - the apparant line powers' by

$$\left(\frac{L_j}{Q_o}\right) = F(n)\,\delta n \qquad (40)$$

the values of L_j when weighted as below to compensate for the use of a finite instead of an infinite set of data give the final U_j's - representing an estimate of the average energy over a finite frequency range resulting from a finite data sample. The statistical reliability of the U_j distribution is, however, fairly easily determined since, if it is assumed that the original data series is distributed normally, then the spectral estimated U_j from different samples, provided they contain the same number of observations, will be distributed as chi-square for the f_d degrees of freedom given by equation 36 (Tukey, 1958). Thus having established an f_d value the confidence limits for the U_j of each frequency band may be found by reference to the χ^2 distribution found in any statistics handbook.

Plotting F(n) (expression 27) as a function of frequency gives a form of the energy spectrum curve. Multiplying F(n) by n, the frequency band of width $\left(\frac{1}{2m.\delta t}\right)$ centred on n and plotting on similog paper gives a more useful form of the energy spectrum curve. The area beneath this curve, bounded by the frequency axis and the ordinates n and n + δn represents the contribution to the total variance from the frequency range δn because

$$\int_{n_1}^{n_2} nF(n)d(\ln(n)) = \int_{n_1}^{n_2} F(n)dn = \sigma^2_{(n_1\ n_2)} \qquad (41)$$

(from preamble to expressions 26 and 27) and hence the total area bounded by the curve when extended to infinity is the total variance.

Strictly speaking since the estimate at the point n is the average estimate over a given frequency band-width, the plot of nF(n) against n ought to have; the appearance of a histogram - horizontal lines through the nF(n) value corresponding to n being drawn parallel to the n-axis and of width equal to the band width. However, the convention of joining the centrepoints of the bands is a useful and acceptable one since it permits easier comprehension of the pictures when comparisons are being made.

Finally the series is smoothed by using a three term weighted average to give the smoothed estimated U_j

$$U_j = 0.54\ L_j + 0.23\ (L_{(j-1)}) \qquad (42)$$

the constants 054 and 0.23 are weights found by experience (Tukey & Blackman 1958) to provide the best smoothed estimates. The time interval δt between digitised points should be made as small as possible (here taken at 0.015 secs) in order to minimise error due to aliasing; alias values could result from taking too widely spaced readings, producing a lower frequency than that truly observed.

It is also possible (as has been found) that the spectrum of energy may vary rapidly as a function of the frequency and yield poor estimates of the spectral energy contributions. Because of this the series corresponding to the vector wind components should be processed to give a new series with a spectrum in which the high frequency fluctuations are emphasised relative to the somewhat low frequency fluctuations. The transformation is linear using Tukey's weighting:

$$Y_i = X_i - 0.75\, X_{(i-1)} \qquad (43)$$

In the power spectrum of this new series the U_j* values corresponding to the U_j of the original series are given by:

$$U_j = \frac{U_j^*}{(1 + 0.75^2) - 1.50 \cos\left(\frac{\pi h}{m}\right)} \qquad (44)$$

Values of frequency, energy, velocity, turbulence components, variances and combinations of these can be compared under an arguement such as stability or height.

APPARATUS

Wind speed and direction

At a series of heights over a homogenous surface a continuous record is required of the fluctuations in temperature, vapour pressure and the three normal components of wind speed. Such apparatus is expensive and difficult to maintain in the field so that one set of probes was used at successive heights. Mean values of wind speed, temperature and humidity were taken from the run of the wind measured by cup anemometers and from repeated values of wet and dry bulb thermocouples in shielded, aspirated mounts - as outlined in the report on heat balance at the glacier surface. For recording high frequency fluctuations in an air layer close to a natural surface a device is required capable of extremely fast response, with small dimensions yet physically robust and capable of retaining calibration factors over a reasonable period of time. This instrument must be very sensitive to changes in wind speed and direction.

Ower (1966) described the range of instruments for air flow measurement and Jones (1957) concluded that the hot wire most nearly fulfills the above requirements.

Various geometrical shapes of platinum wire and foil were tried but the best compromise was a directional probe as in figure 25 for which Jones kindly loaned an angle gauge to facilitate achieving identical geometry in repeated probes.

Each probe wire was left for 6 hours in still air at a dull red heat to attempt some annealing and hence stability of the material. Also to encourage stability and delay the need for recalibration, the wires, before a series of readings, were washed in the fine jet of pure alcohol.

The cooling effect of the wind per unit of wind, decreased with higher wind speeds as the measured current along the wire changes very little over the higher wind speeds. For this investigation it was not profitable to observe in wind speeds 10m sec^{-1} since the apparatus could suffer. Hence two velocity probes were arranged in a single mount as in fig. 2,5 one probe for 0 to 6 and the other for 4-9 m sec^{-1} withsensitivity similar when expressed as a percentage of mean wind for each probe. This involved shifting the zero off the scale (i.e. off the paper of the recording galvanometer) for the high speed probe and entering the calibration curve at a point in the overlap of the wind speed scales. Wind speeds observed in the field were low so this method of transfer between probes was unnecessary.

The two V's of the directional probe shown in figure 2.5 were in opposite arms of a Wheatstone net, measuring the increased cooling of one V as the angle of the attacking wind diverged from the axis of the probe. A second probe but mounted at 90° to that shown in figure 2.5 measured inclination. The velocity probe, was in one arm of a wheatstone net and to give temperature compensation the opposite arm had two identical wires lying in open holes through a polished perspex block exposed to radiation and air temperature changes, but insensitive to changes in wind speed. Micro changes in wind direction affected a wind vane on which the probes were mounted. Output from a low torque servo potentiometer geared under the vane was also recorded by a multi channel galvanometer.

The circuit in figure 2.6 was operated with constant input of 5v. To retain freedom of the vane and permit remote reading, power leads were used the resistance of which was comparatively high, and kept purposely so, to give 3v across the bridge and reduce effect of low wind speeds on the directional wires. We are very grateful to Dr. L. Molyneux for considerable assistance and design in this curcuit, and to Dr. D. Tritton for helpful discussion of aims.

The recording galvanometers had a sensitivity of 1 mm deflection per micro amp and a natural frequency of 90 cycles $sec.^{-1}$ which was 3 to 4 x the max frequency of the air turbulence it was hoped to record.

Before the recording galvanometers were plugged in, each circuit was set to zero on the initial test galvo, the attenuators being brought to zero in turn and then raised, according to the wind speed and turbulence, to give a small deflection which would be readable on the recorder galvo but would avoid serious overlap of the traces. The recorder was connected, the zero setting galvos switched out of circuit and a perspex box held over the hot wires to shroud them in still air until the recording galvos had been positioned in sequence and their zero deflection positions recorded on the photographic paper. Paper was used in preference to film to permit processing in the field without a perfectly light-tight procedure. The hot wires were them exposed and the galvo deflection checked for position and amount of trace overlap. Re-positioning and a new zero was often necessary.

Temperature.

A 0.0028 ins (45 swg) copper constantant thermocouple junction was mounted in a horizontal double, concentric radiation screen on the vane mounting with a reference junction in the vacuum flask with thermometer. A series of 5 similar thermcouples was arranged round the nose of a short perspex rod in similar screens. The down-wind end of the rod was identically arranged but shrouded in a linen stall with wicks feeding water from a small reservoir screwed under the screens. Change in output from the dry bulb thermocouple and from the wet/dry couples was amplified (figure 2.7) to give a deflection on the recording galvanometer of 1cm/40 micro volts. The system was only intermittently successful, one fault being the pick up by the amplifier of stray fields, particularly if the recorder was 1 metre distant.

Calibration

It was difficult to make the timer give precise 1 second intervals so was accepted at 7 strikes each 6 seconds. The effect of temperature on the time components was 0.001 sec C^{-1}.

The arrangement of 3 probes; inclination, velocity and declination in the form of a plug-in unit at 5 cm spacing on the aerodynamic section of the wind vane is illustrated in figure 2.8. The declination probe is shown positioned in the wind tunnel for calibration.

The wind tunnel was kindly put at our disposal by the National Coal Board, North Division Laboratory. The probe was aligned along the tunnel in the grid reference position (0,0) the zero box put over the wires and a zero deflection recorded. With the wind at a selected speed and the probe still occupying (0,0) about 2 cm of record was run off.

The probe was then swung to the extremes of inclination and declination allowed by the tunnel dimensions, consistent with a couple of cm of wall clearance, and a further 2 cm or record taken. From this position (+20°, + 20°) the probe was successively moved by 5° intervals through a spherical cartesian coordinate grid until the point (-20, ° - 20°) was reached. 2 cm of record being made at each reference point. Hence a calibration run would ideally contain 120 readings for each particular wind speed, but because the tunnel was octagonal in section, some of the extreme positions had to be sacrificed. Calibration was repeated at wind speeds 0.2; 0.4; 1.0; 2.0; 4.1; and 7.6 m sec^{-1}.

(Figure 2.9a) shows the response of the inclination probe at constant values of inclination over the declination range at 2.0 m sec^{-1}. The reflection of the tunnel cross-section can be seen in the octagonal shape of the distribution of the grid points. The pattern indicates loss of linearity in response beyond the range (± 15,° ± 20°), but, since the probes were to be mounted on a vane structure which, should the wind veer more than 10° - 15°, would rotate to compensate, it was sufficient to base calibrations over only this range. (Fig 2.9b) illustrates the behaviour of the same probe as in 2,9a between the chosen limits of declination response (±15°) for inclination 0°, 10° and 20° over the range of wind speeds 0.2 to 7.6 m sec^{-1}. Using such pictures as these as guides to defining limits on the useful ranges of the probes, and averaging the response over wind speed ranges produced calibration curves of the form shown in figure 2.9c.

A similar course of action to the above was taken in the calibration of the directionally non-responsive 'velocity' probe. A straightforward plot of deflection against wind speed and the subsequent linearisation to obtain an expression suitable for computer programming needs, are graphically demonstrated in figure 2.10a. Figure2.10b, shows the effect on the velocity probe of a (± 20°, 0) change in the wind. As can be seen, the effect can be ignored between ± 15° declination.

DATA PROCESSING

The natural frequency of the galvanometers was 80 cps and the sensitivity of the hot wires 50 cps so the photographic trace of the output from the wires can be considered satisfactory for analysis of frequencies up to say 30 cps. A single record comprised 10 secs. of continuous trace at each of 5 heights, generally 150, 100, 50 25 and 10 cm. These were successive recordings between a zero record at beginning and end of each complete run. Fig.2.11 is a typical framewith scales added from calibration curves. Sections of film record were selected on the basis of sharpness or image, good zero references, clear time interval markings and minimum overlapping of trace images. Overlapping often precluded digitising of values from a particular trace. The initial film was 7 cm. wide so was enlarged by a factor of 3 using a good quality paper to minimise distortion a precise enlargement factor was calculated for each frame.

The enlarged records were digitised to produce punched paper tape carrying coded information relating directly to the displacement of the data points from a zero reference.

Data were abstracted from the charts every 0.015 sec intervals, the upper frequency limit set at 30 cps and the decision taken to estimate the spectrum over 30 lags. Hence from the equations 31-35 an estimate of ϵ_e for an average of 500 data points is 0.25. This value is poor. It could be improved by decreasing m but resolution would be lost or by increasing N. For $\epsilon_e = 0.10$; (selected by many workers) $n'_{cps} = 30$; $m = 30$ and $\delta t = 0.015$ sec

$$N = \frac{30}{0.01} = 3{,}000 \text{ data points}$$

$$\text{or } T = 45 \text{ sec}$$

Hence total record is only one quarter of that theoretically required.

From the same equations (31-35), a sampling time of 0.015 sec gives an upper frequency limit of 30 cps and the chosen value of m a lower frequency limit of 1 cps approx.

Declination data was corrected by adding the vane deflection (see figure 2.11)

Programmes to achieve the expressions outlined in the section on time series analysis were written in Algol 60 for use on the English Electric KDF/9 computer.

RESULTS

Figures 2.11 and 2.12 show a sample of the record with scales added. The range of inclination is less than that for declination, and there is an increase in frequency and amplitude at the lowest height. Such may be expected near the ground but the increase in mean velocity at the lowest height is not expected. This reveals a marked weakness in the short length of record. It will be seen that only a small part of the long period fluctuations (with period of, say, 5 to 30 sec.) is indicated over the short record. Hence deviations about a mean value, which are used as an indicator of energy inherent at the frequency, may be exaggerated since the mean may not be a horizontal line through the values shown. In some cases the record of each trace could be taken in parts with a different linear trend assumed for each and micro fluctuations measured from these. This is difficult and somewhat subjective so deviations were measured from the simple arithmetic mean of the series.

Correlograms - Turbulence Pattern

As a measure of persistence of a pattern in the turbulence, the auto correlation series (expression 28) was calculated for the three velocity components as derived from the model (expression 21), and typical correlograms are shown in figure 2.13. Where the correlation fluctuates at low values there is no recognisable pattern and motion is completely random. It will be seen that the rate of decay of a dominant pattern, represented by the fall off in the correlation, was nearly linear over the first few data points. To indicate this initial rate of decay, the area under the correlogram was measured over the first 5 data points, i.e. from 0. to 0.075 seconds. The total area under the correlogram between times of unity and zero correlation is a measure of the persistence of a pattern in the turbulence. The repetition of a particular shape in the autocorrelogram may be an indication of harmonics but these could not be recognised with sufficient precision to compare data at different times and conditions. The first area represents the initial persistence or the inverse of a rate of decay of a particular turbulence pattern, while the second, larger area, is a measure of the persistence of any pattern in the turbulence. These values against height and against stability showed a wide scatter as in figure 2.14 The stability index (expression 12) was derived from mean gradients of wind speed and temperature observed over 10 to 15 minutes, the time taken for setting up, checking and reading the hot wire probes at four different heights. The sampling time at each height was only 10 seconds, so the value of the Richardson number was far from precise but considered a rough indicator of stable, neutral or unstable conditions. An alternative stability index based on the net radiation and wind speed was tried but was most inadequate, particularly for the night hours. The turbulence pattern was rapidly curtailed for the inclination component w, was slightly longer for declination, v, and persisted longest for the velocity component u. Figure 2.14 suggests that the turbulence pattern could persist appreciably in the neutral atmosphere but was rapidly damped by a marked temperature gradient.

Some of the correlograms showed a more gentle fall to a weak value of correlation that persisted long after the v and w components had fallen to fluctuate about a zero value of correlation. Eliminating these measured areas reduced the scatter but the mean values did not show a systematic change with stability very different from that indicated in figure 2.14 Persistence of the turbulence pattern increased to 1m. height but the rate or decay was least at approximately 25 cm. (figure2.17). There were too few data at heights above 1 m. to permit firm conclusions on the suggested decrease in persistence there. It must also be remembered that data at different heights were not recorded simultaneously, but successively, and though averages have been taken at each height, there was a wide range of wind speed.

Thus though the sought after patterns of turbulence might each be the same in wavelength, they may not have been carried across the probes at the same average speed. Direct comparison therefore of correlograms may indicate that because one decayed more rapidly than another, the eddies associated with that air flow were smaller, when the real reason behind a more rapid decay could be a higher wind speed sweeping the pattern more quickly across the measuring probe. Alternatively if the frequency of turbulent eddies is a linear function of wind speed carrying those eddies, then the higher wind speed will have a reduced pattern associated with it. Then the rapid decay of a correlogram for a pattern borne by a high mean velocity will be a real reflection of the eddy size. This questions the comparability of the output from 3 probes having a horizontal spearation across the wind and thereby not recording behaviour at a point. The time correlograms as in figure 2.13 were changed to space correlograms by reading off values of correlation at abscissa intervals of $\bar{u}t$ and integrating the area under the new curve; but with little improvement in the overall result.

Scale of turbulence

A more successful inclusion of mean wind speed with the area under the autocorrelogram was suggested by Taylor (Pasquill 1962, p. 3.) who defined a quantity l by

$$l = \int_0^\infty R(x)dx$$

in which x is the decreasing distance between a fixed and a moving probe. The product of the mean wind speed and the area under the autocorrelogram gives units of length so for this scale of turbulence we may put

$$l = \bar{u} \int_0^\infty R(t)dt \qquad (45)$$

This is only valid if the integral converges, a condition not generally satisfied at the higher time values, as shown in figure 2.13 However, as a check on the lower time values and the expected exponential decay of turbulence, some of the autocorrelograms were expressed as

$$R(t) = e^{-\alpha t} \quad \text{giving} \quad \log \left(R(t)\right) = -\alpha t \qquad (46)$$

as shown in figure 13.

It will be seen in figure 2.13 that the rate of decay of the average eddy size (which the autocorrelograms conventionally show) is arrested at approximately the same point in time for each of the three curves; e.g. at 100 cm. the curves show a more marked discontinuity at 0.315 sec or (times $\bar{u}$) on a length scale at 27 cm. Similarly in figure 2.13 at 10 cm the first marked discontinuity occurs at 0.18 sec. or 6 cm. The curves at 25 cm. are less clear but an anomaly occurs at a time scale of between 0.18 and 0.23 sec. equal to a length scale of 13-16 cm. These values can also be found using the slope from expression 46 above with the value of R(t) at which the anomaly (and change in exponential rate of decay) occurs. Locating this point is somewhat subjective so an attempt was made to continue the smooth correlogram curve, as though the disruptions were anomalies, and find the time at which the curve reached a minimum. Neither method gave values that showed a very significant pattern with height but were like figure 12.

Returning to expression 45 for the scale of turbulence- figure 2.17 shows the increase in scale of turbulence with height. The standard deviations are disappointingly great, but some of this spread is due to the wide range of stability observed. Each plotted point is a mean of 6 values save at 150 cm. where only 3 values were available. The scale of the velocity component between 10 and 100 cm. suggests an approximate rate of increase of $l \propto 0.28z$. The scale of turbulence derived from the slope of the exponential rate of decay and from the break in the correlogram curve gave slightly smaller values, whereas scale from the smoothing of the correlogram to achieve the time of minimum correlation gave slightly higher values. In figure 2.17 it should be noted that in general, the scale of the velocity component is greater than the declination and inclination component by a factor of 4. The maximum scale at 100 cm. and lesser maximum at 25 cm. is very doubtful though Chapil & Siddoway (1959, p. 416) found a maximum in relative magnitude of turbulence at 25 cm. over 10 cm. gravel ridges. For magnitude they used $6\sigma/\bar{u}x$.

In figure 2.18 the spread of data is similar to that of figure 2.17 from which the scale values have been derived, but to clear the picture, values of l have been averaged in stability groups, but the plotted points are at the mean Ri value in each group. Each point is a mean of 5 values save at extremes of stability where only 2 values were available. Within the frequencies here analysed (1 to 30 cps) the scale of turbulence of the velocity component reaches a peak at small instabilities and decreased as stability departs from near neutral. The rate or decrease is very marked for the stable region. Scale of turbulence for the declination and inclination components shows small increase from the very stable through neutral to the most unstable regime.

Intensity of Turbulence

Various expressions for the intensity of turbulence were tried, generally using variance values. There is some doubt whether the measure of deviation can here be called a 'variance' since each value of the series taken from the traces must bear some relation to those immediately on either side of it. Hence the mean square of these values is not a variance unless it is assumed that the air motion is completely random. Furthermore, use of 'variance' values gave intensity in units containing velocity so intensity I was expressed as the ratio of the standard deviation of each component to the mean velocity

$$I_u = \frac{u}{\bar{u}} \qquad (47)$$

Figure 14 shows a rapid decrease of intensity with height up to 50 cm. For the next metre height, only a small decrease is shown, save by the mean for the declination component which has a slightly higher value at 100 cm. than above and below. The mean slope of the intensity for the velocity component is 0.005 between 10 and 50 cm. which compares with Chepil and Siddoway's (1959 p. 416) slope of 0.009 for the same range of height but over gravel ridges 10 cm. high and 40 cm. wide. Intensities are in the approximate ratio of 1 : 1.8 : 16 for the inclination, declination and velocity components, respectively.

Friction velocity

The mixing length hypothesis of Prandtl, though so successful in its result (expressions 4, 5 and 6) and applicable to an extremely wide range of wind speed data, is now looked upon as a convenience that has little practical support. It is worthwhile here, after discussing the similar parameter, scale of turbulence, to link the micro observations with the wind profiles used in evaluation of fluxes summarised in the heat balance and micro met reports.

Values of u* (see expression 1 and preamble to expression 8) were very low since wind speeds observed were also low, but in very few cases was wind speed increasing linearly with height, so laminar flow was rare.

Nikuradse's criterion for rough flow, evolved from measurement of sand grains round a circular pipe is of doubtful application to these natural surfaces but was applied to check on rough or smooth flow.

Nikuradse's limiting condition for smooth flow

$$\frac{u^* z_o}{\nu} > 2.5$$

where u* is the friction velocity
z_o is the coefficient of surface roughness
ν is the kinematic viscosity

Values of z_o from mean wind profiles ranged widely about 1 mm. but using profiles of highest wind speeds only, gave a value of 7 mm. This is in fair agreement with typical values given by many workers, e.g. Priestley (1959, p.21). From the above expression the critical u* became 0.46 which was smaller than most of the values found here. This suggests aerodynamically rough flow but considering the lower values of z_o there was a marked tendency to a transition region between rough and smooth flow. Shear stress τ is assumed constant in the first few metres of height but this breaks down in the transition region, hence values of u* were not constant but neither was there any significant relation-with height. The ratio of the shear velocity to the wind at a specified height is known as the drag coefficient, C_D.

$$C_D = (\frac{u^*}{u})^2$$

This was not constant but showed less spread save at extreme stabilities (Deacon 1957, p. 537).

The low wind speeds experienced gave a wide range of stabilities with some very high values of Ri (expression 12). Figure 2.19 shows a rapid decrease of u* to an approximately steady value as Ri changes from + to - which is very similar to a previous result (Grainger and Lister, 1966, p. 126) in which the friction velocity fell to a steady low value at Ri = 0.2.

Mixing length and Von Karman's constant

Profiles of mean wind speed have been discussed in the heat balance results, in which, though a logarithmic law (expression 8) gave the best fit, it was not always a good fit and in some cases was improved by fitting with a different slope to two overlapping height intervals. This prompted further comparison of results from cup and hot wire anemometers.

From expressions 4 and 5 the mixing length

$$l = \frac{u^*}{(du/dz)}$$

Mean wind profiles here represent a time in minutes whereas deviations from the mean wind, giving values of u* were from hot wire records over seconds. These mean wind speeds recorded by the hot wires were generally less than the mean run of the wind recorded by cup anemometer. In the low, but very variable winds experienced, this difference was thought to be the result of the difference in time of observation of the different instruments and the inertia of the cup anemometers. Values of l are thus only an indication and have a large spread about the mean value for each height. This is shown as a standard error in figure 2.20 with 5 values at each height. Considering this approach, the linear increase of mixing length with height is remarkable, but the rate of increase is 0.114 and not Von Karmans 0.4.

Since the Von Karman constant k appears in K_M the coefficient of eddy viscosity (expression 10) which was used for calculation of heat and vapour transfer, though with only moderate success, it may be worth further consideration. Furthermore the form of flow in some cases here seems transitional between smooth and rough. In both, without consideration of temperature, the wind profile can be expressed

$$\frac{du}{dz} = \frac{u^*}{kz}$$

and (see expressions 6 and 9) $K_M = k^2 z \left(\frac{du}{dz}\right) = ku^*z$

Priestley (1959, p.23) goes from this to add a stability term $f(s)$ and introduces

$$K_M^* = \frac{K_M}{u^*z} = \frac{k}{f(s)}$$

from which it can be seen that "K_M^* can be regarded as a generalised form of the Von Karman 'constant'".

From expression 4 and 9

$$\frac{\tau}{\rho} = u^{*2} = l^2 \left(\frac{du}{dz}\right)^2 = K_M \left(\frac{du}{dz}\right)$$

$$K_M = l^2 \left(\frac{du}{dz}\right) = \frac{l^2 u^*}{l} = lu_*$$

and from $K_M^* = \dfrac{K_M}{u^* z} = \dfrac{l}{z}$

Values of K_M^* found from (44) are shown against stability in figure 2.21. It will be seen that values are all below the expected mean value of 0.4 and spread about the derived value of 0.114 though the doubtful derivation of l must be borne in mind.

Holzman, from empirical results, accounts for stability effect by the relation

$$K_M^* = k(1 - c_2 Ri)^{\frac{1}{2}} \qquad (48)$$

though at moderately positive stabilities the last term becomes a negative quantity and the expression fails. With $c_2 = 8$ (a constant found to fit some data) this expression for K_M^*, as shown in figure 2.21, represents the data very badly; with such a scatter of data a good fit was impossible but a trend was expected. For stable conditions, Rossby and Montgomery suggested

$$K_M^* = k(1 + c_1 Ri)^{-\frac{1}{2}} \qquad (49)$$

which fails in strong lapse conditions ($Ri \leqslant {}^{-1}/c_1$). Sverdrup suggested a value of 11 for the c_1 but the resulting expression for K_M^* as shown in figure 2.21 gives much too high values. Only a reduction in the constant k permit the values of K_M^* derived here over the wide range ofstability. Hence the value of k = 0.114 found from figure 2.20 has been used in expression 49 with c_1 at 2, 5 and 10. The improvement is encouraging but the weakness in deriving l and the scatter of values does not warrant pursuit of this to derive a further expression for wind speed variation with height. It does indicate that even when wind observations approximate to the logarithmic law, a transition region between rough and smooth flow demands consideration of constants used to derive K_M particularly if this is to be applied for flux measurements.

Energy Spectra

The opening remarks to the section on the semi-rigorous development of the theory of time series analysis mentions the requirement of normality in the series to be investigated. Figure 2.27 shows a typical frequency distribution of the u, v and w components with a Gaussian curve for a normally distributed random variable having the same standard deviation and identical central density. It can be seen that the components are not normally distributed. Robinson (1959, p. 262) also found non Gaussian results further complicated by a step function in the vertical wind record and a non zero mean. The distrubutions for the v' and w' values are very similar and deviate from normal by the single high peak at mean values. At present there is little alternative approach but conclusions based upon assumed normality must only be tentative.

The contribution to the total variance by successive frequency bands has been calculated from expression 40. The trace records used for the autocorrelograms in figure 2.13 are shown after this further development in figure 2.22 as energy contained within specific frequency bands.

Figure 2.24 depicts the 'smoothed' line power spectra-smoothed with the weighting factors of expression 42. A noticeable feature of the distribution in general is the fair degree of smoothness showing a continuous flow of energy down through the frequency bands. This definitely suggests a continuous range of eddy sizes from about the 5 cps band up to 15 cps at which frequency the curves exhibit a tendency to rise with increasing frequency. Generally speaking the v and w spectra reflect each others behaviour (cf. at 10 cm. the small peaks at 2.2; 4.5; 10 and 22 cps and the two spectra above 15 cps at 50 cm.). At low heights (below 100 cm.) all the spectra are spearated, the u component ordinates being 10 - 20 times the length of those of either the v or w component. At all heights and especially above 100 cm. (with the exception of that shown at 50 cm) the v and w spectra lie very closely together over all frequencies considered.

The u component, expect in the case of 25cm shows no definite peak, the spectrum suggests in fact that portions of the 'linear' part of it lie at frequencies lower than 1 cps, yet in both the v and w component spectra, definite peaks are shown which tend to shift to the higher frequencies in passing from the lateral to the vertical components - cf. heights 50 and 100 cm. and in particular 25 cm where this is well displayed.

Figure 2.25 apparently presents an inverted picture to that in figure 2.24. This is because it is usual to find that the u-variance is very much greater than the v-variance which in turn is slightly greater than the w-variance; hence division by the variance factor results in the plot of fig. 2.25. Putting aside the question of relative positioning for a moment figures 2.25 and 2.25 are interesting on 3 counts. The first is the tendency for the nF(n) function to leave the linear form seen to hold between approx. 5 and 20 cps at above

100 cm and to become increasingly more curved at the lower heights. The line AB with the spectra shown has slope exactly $^{-5}/3$. This result would seen to corroborate Kolmogoroff's law derived from similarity theory were it not for the fact that the involvement of an extra factor n in the abscissae of the plots should have caused the slope to have a value of $-\frac{3}{8}$. and not $^{-5}/3$. This must be so if it is assumed that

$$nF(n) \propto n^{-\beta}$$

$$\text{i.e. that } F(n) \propto n^{-\beta-1}$$

If the slope in general of the nF(n) against n curves is in fact $^{-5}/3$ as is strongly suggested by the plots above 100 cm figures 2.25 and 2.26 then this implies a value of β for the range 2 - 20 cps such that

$$\beta - 1 = {}^{-5}/3$$

$$\text{or} \quad \beta = {}^{-2}/3$$

Since departure from linearity seemed to be exaggerated with proximity to the ground a quadratic was fitted to that part of the spectrum between 5 and 15 cps. of the averaged u, v and w components from six runs at 10 cm. height.

Table I shows the values of the coefficient m_1, m_2 and m_3 in the general quadratic expression $\ln(nF(n)) = m_1(\ln(n))^2 + m_2 \ln(n) + m_3$

TABLE I

Component	m_1	m_2	m_3
u	-1.36	+ 4.18	-5.54
v	+0.41	-2.90	+2.44
w	-0.71	+2.20	-2.92

VALUES OF COEFFICIENTS IN BEST FIT TO u, v and w SPECTRA

This curvilinear regression only fits over the 5 - 15 cps section of the spectrum and has a peak not coindident with that of the energy distribution. However, the basic similarity in the general shape of the curves of all 3 components, which property is not confined solely to one height but seems to be the case over all heights observed, does indicate that there may be a general form of the F(n) function which is universal for the high frequency spectrum of all 3 components of turbulence between 5 and 20 cps. This function is non-linear and possibly height dependent - becoming less linear as the ground is approached.

The second point has already been mentioned and is concerned with the order of the curves on the F(n) axis in figure 2.25 as compared with the intuitively more acceptable order indicated in figure 2.24. By dividing by the variance for that component (figure 2.25) it was hoped that some idea might be gained as to the manner in which the total energy available was apportioned among the 3 components and to see how this fraction compared from component to component. It is seen from figures 2.24 and 2.25 that at 100 and 150 cm. both the v and w components lies almost exactly on top of one another indicating that the dividing up of the total available energy is in the same ratio over all frequency bands investigated.

Below 100 cm these two components spearate slightly, the persistently higher variance of the v-components over that of the w causing the curve of the former to fall below that of the latter. In all plots of this nature the u curve falls below those of both the v and w components suggesting that in any selected frequency band the energy contribution from that band to the whole, expressed as a fraction of the whole energy available for that component, is less in the longitudinal than in the lateral or vertical. It is possible that this occurs because much of the relatively larger variance values of the u component (see figure 2.24) are from fluctuations of longer periodic time than the 1 cps lower limit of the analyses which have imposed trends on the data series causing the errors mentioned in the first paragraph of the section headed (RESULTS) to have occurred, with the above consequences. This point is supported by the fact that the u component curves (figure 2.25) do not tend to peak but continue to rise below the 1 cps limit. This error is bound to have occurred in all 3 components but it seems to have affected the longitudinal values to a greater extent than the others.

Finally attention is drawn to the spectrum of all three components above approx. 20 cps in which as the frequency increases the energy curve rises. It is difficult to say whether or not this apparent influx of energy from the environment, sustaining and indeed ostensibly augmenting the energy level in all frequency bands above 20 cps is a real phenomenon or is a result of some inherent defect in the method of analysis. If real, the immediate question is from where comes this energy - heat?

CONCLUSION

Rather than comparing the coefficients of momentum, heat and vapour transfer derived from measured fluxes of these, the experiment had to be limited to the turbulent energy apportioned between the three velocity components over the range 1 - 30 cps. The low wind speeds experienced, many of which apparently falling in the transitional range between smooth and rough flow, caused doubt in the application of generally applied constants in wind speed laws. The friction velocity decreased rapidly with increasing stability. Turbulence patterns were suppressed by proximity of a sufface and increasingly so by a temperature gradient. The scale of turbulence increased rather slowly with height but intensity of turbulence decreased very rapidly in first few dekametres.

The vital factor of recorded trace length, failing to meet the requirements demanded by the analysis, curtailed the low frequency and was possible the reason for the observed separation of the nF(n) spectral curves showing the fractional contribution of frequency bands to the whole energy for that component. From 1 cps up to at least 20 cps the spectra of the three components of turbulence u, v and w had the same shape and were relatively smooth and continuous. Therefore, apart from the differing absolute energy contents, the turbulence (pattern and percentage distribution of energy over the frequency bands) was identical in the 3 directions and existed as a continuous diminishing distribution of patterns of disturbances.

The exteme uniqueness in time and location of the single spectrum makes any generalisation dangerous but more valid conclusion may be drawn from averaged spectra. The nF(n) function against n decreased at a rate conforming to a $^{-2}/_3$ power. This implies that F(n) was proportional to n $^{-5}/_3$; the exponent fell below this value at low heights, where, a quadratic was found to fit the curve far more closely than the linear function.

For future work the experiment should be repeated with a more rigid procedure operating more precise apparatus. Temperature and humidity recording should be redesigned and the wind speed probes more thoroughly checked, particularly with regard to distance between the probes, distance to obstacles and even the possible effect of support wires. Tritton (1967, p.437) 'raises the rather perturbing question of the effect of a hot wire's own stem. Turbulence problems are fraught with difficulties but the application is wide and travel in both current and potential food growing areas pertinently points the need.

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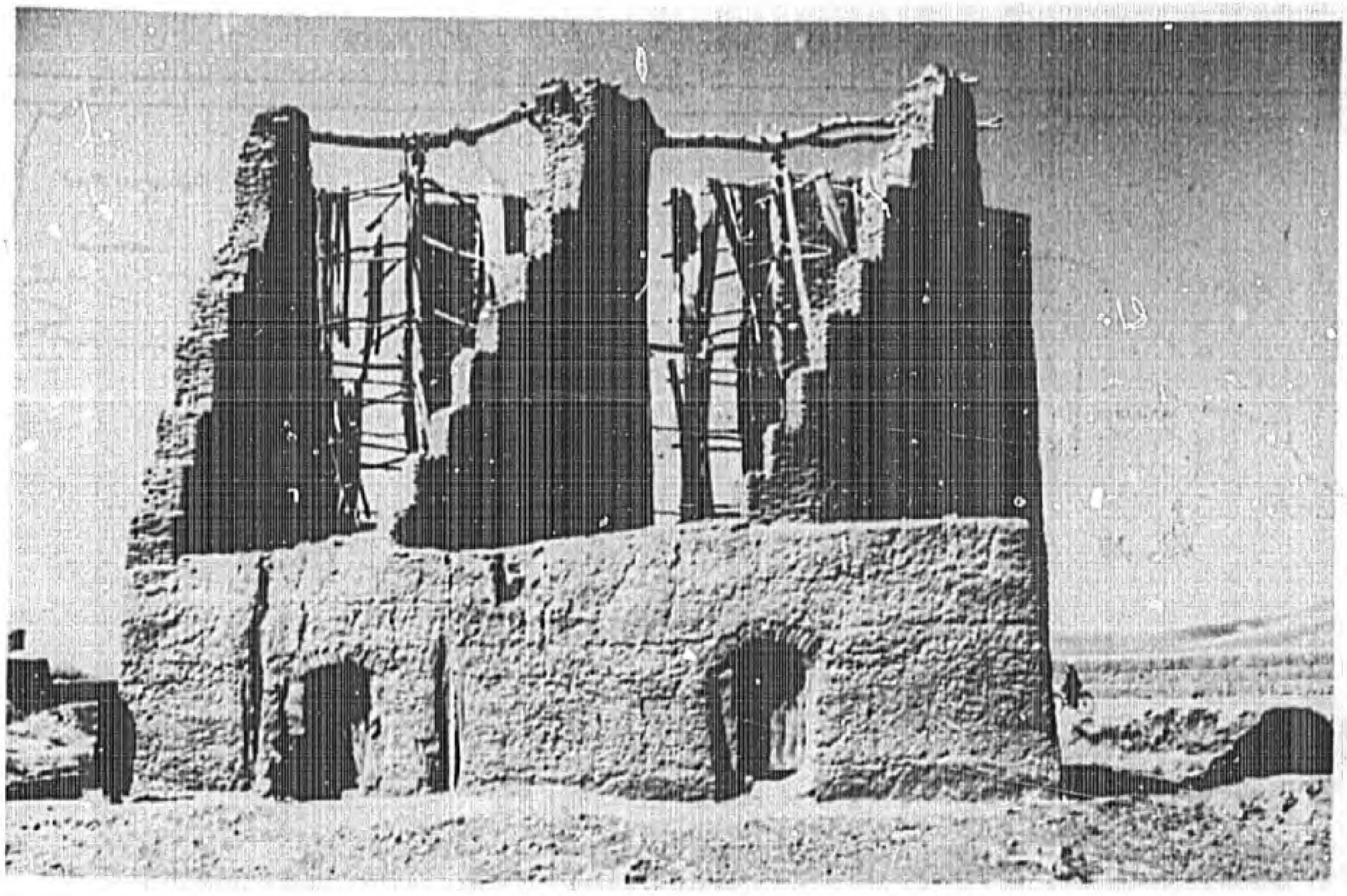


Fig.2.1. Windmill for grinding corn in N.W. Afghanistan. The single vent behind the vertical blades caters for wind from the one nearly constant direction.

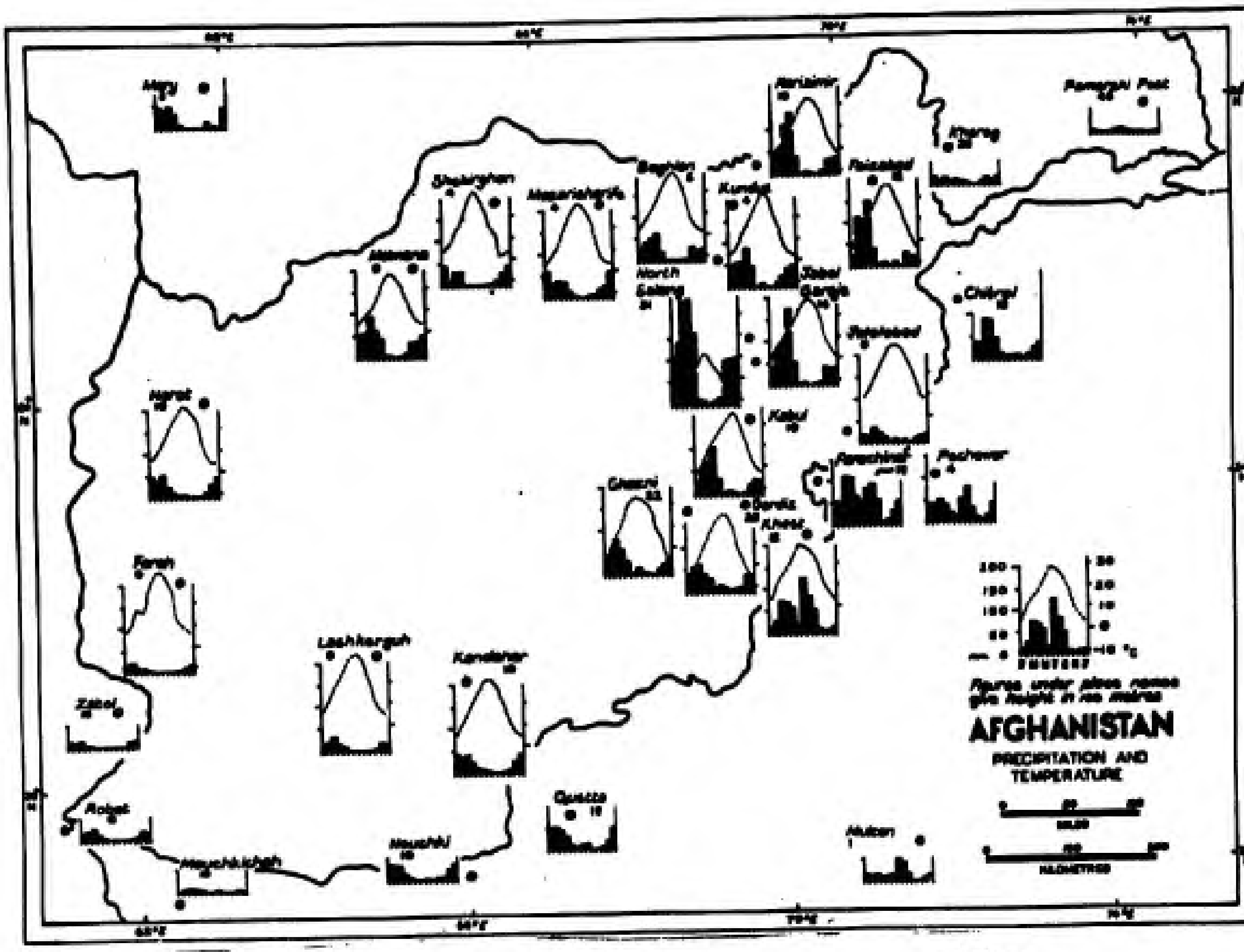


Fig.2.2. Mean monthly figures for precipitation and temperature at stations in Afghanistan and adjacent areas.

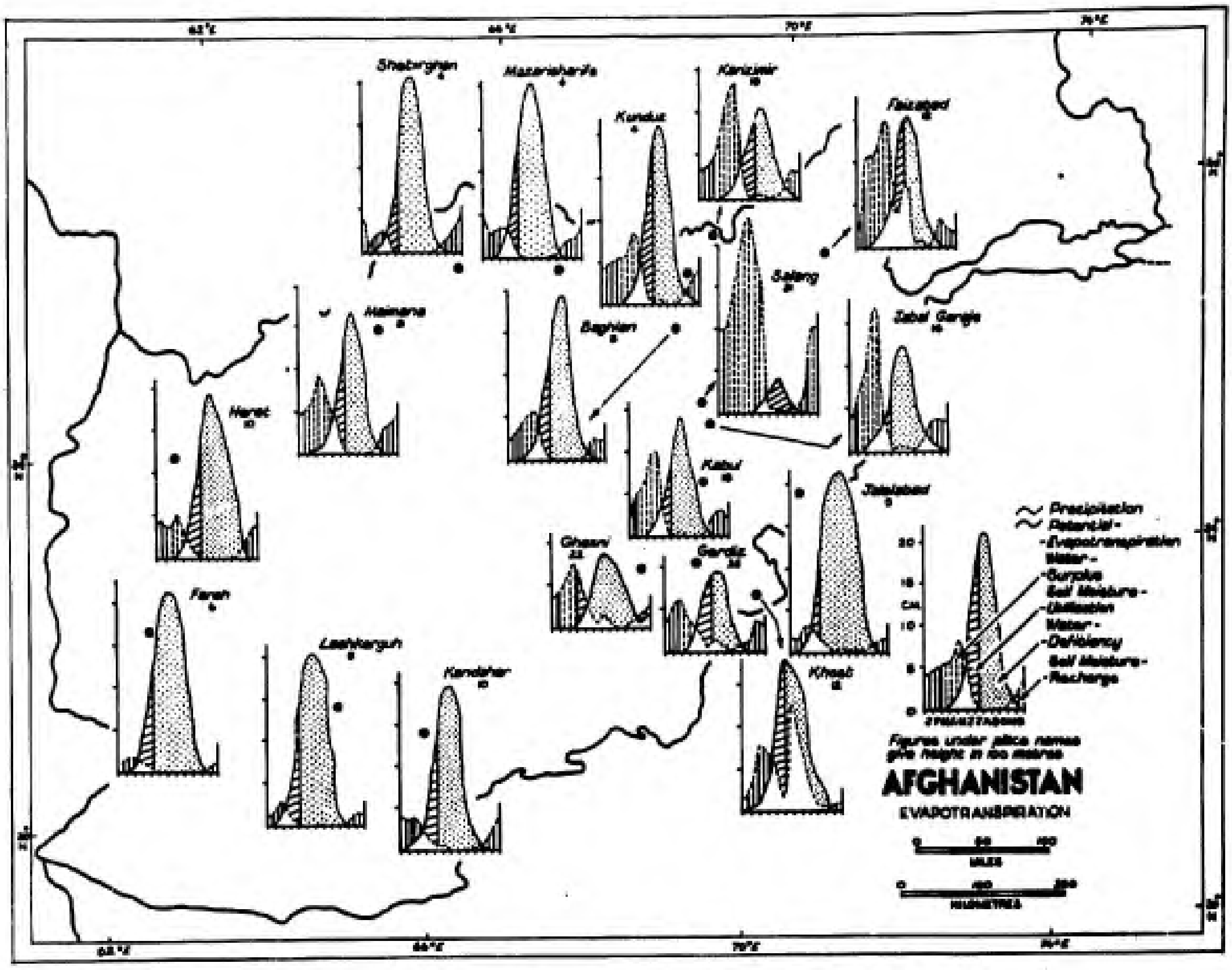


Fig.2.3. Mean monthly figures for evapotranspiration at stations in Afghanistan.

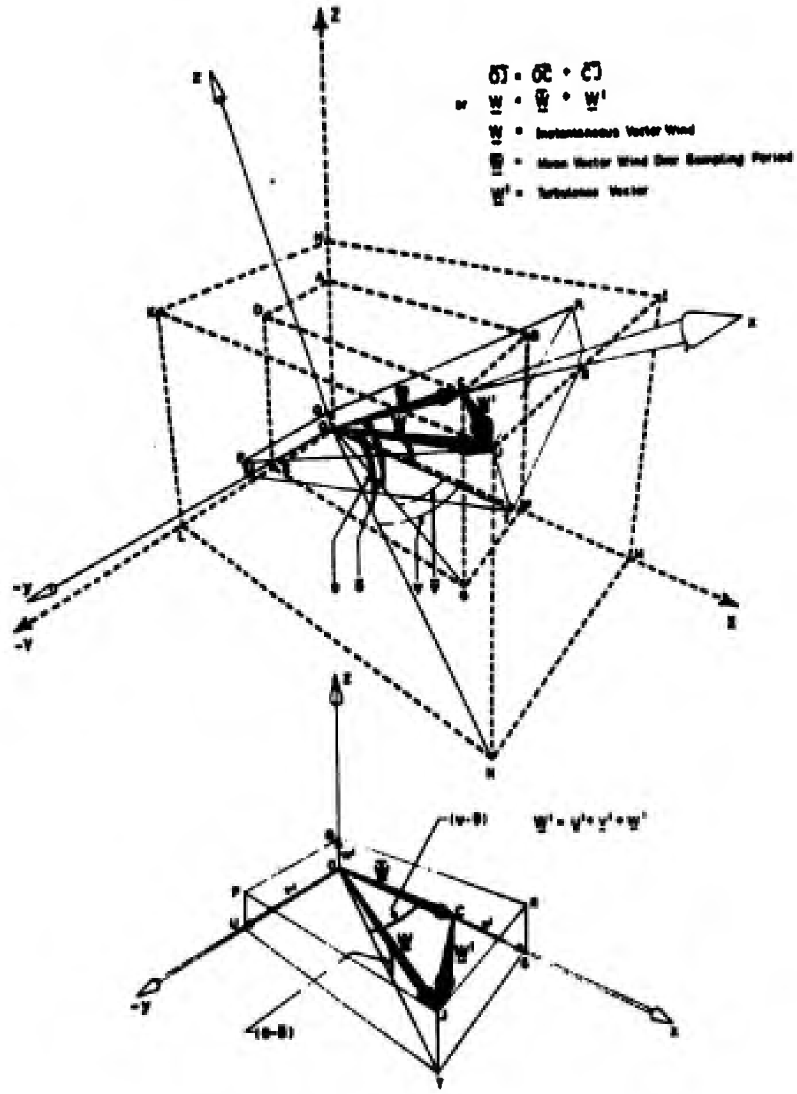
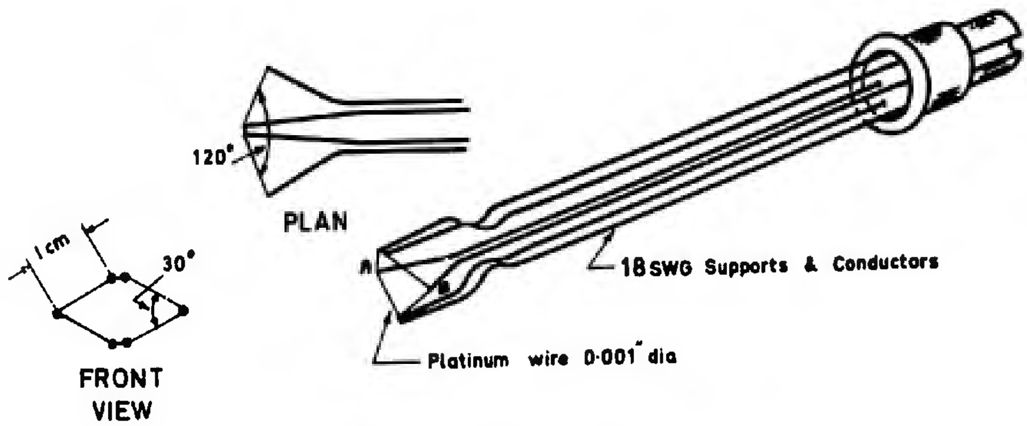
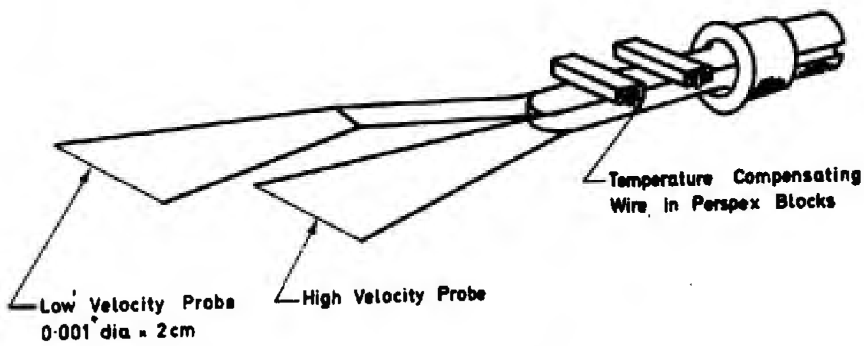


Fig.2.4. Vector model used in derivation of components of turbulence

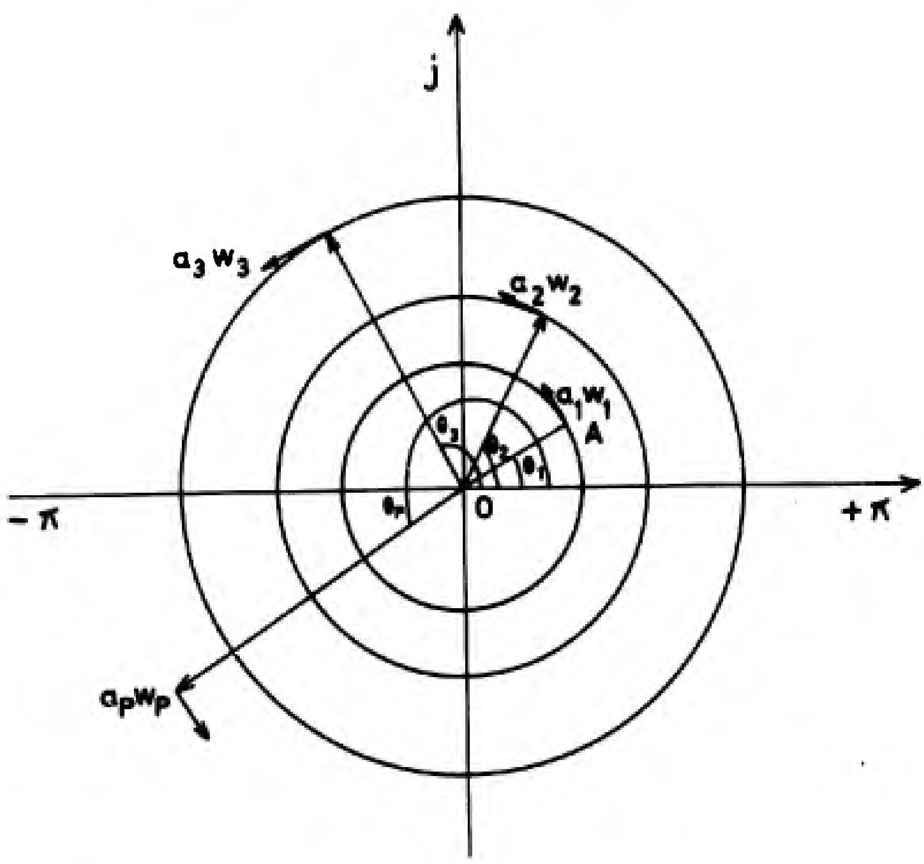


WIND DECLINATION PROBE



WIND VELOCITY PROBE

Fig.2.5. Wind declination and velocity probes



ARGAND DIAGRAM

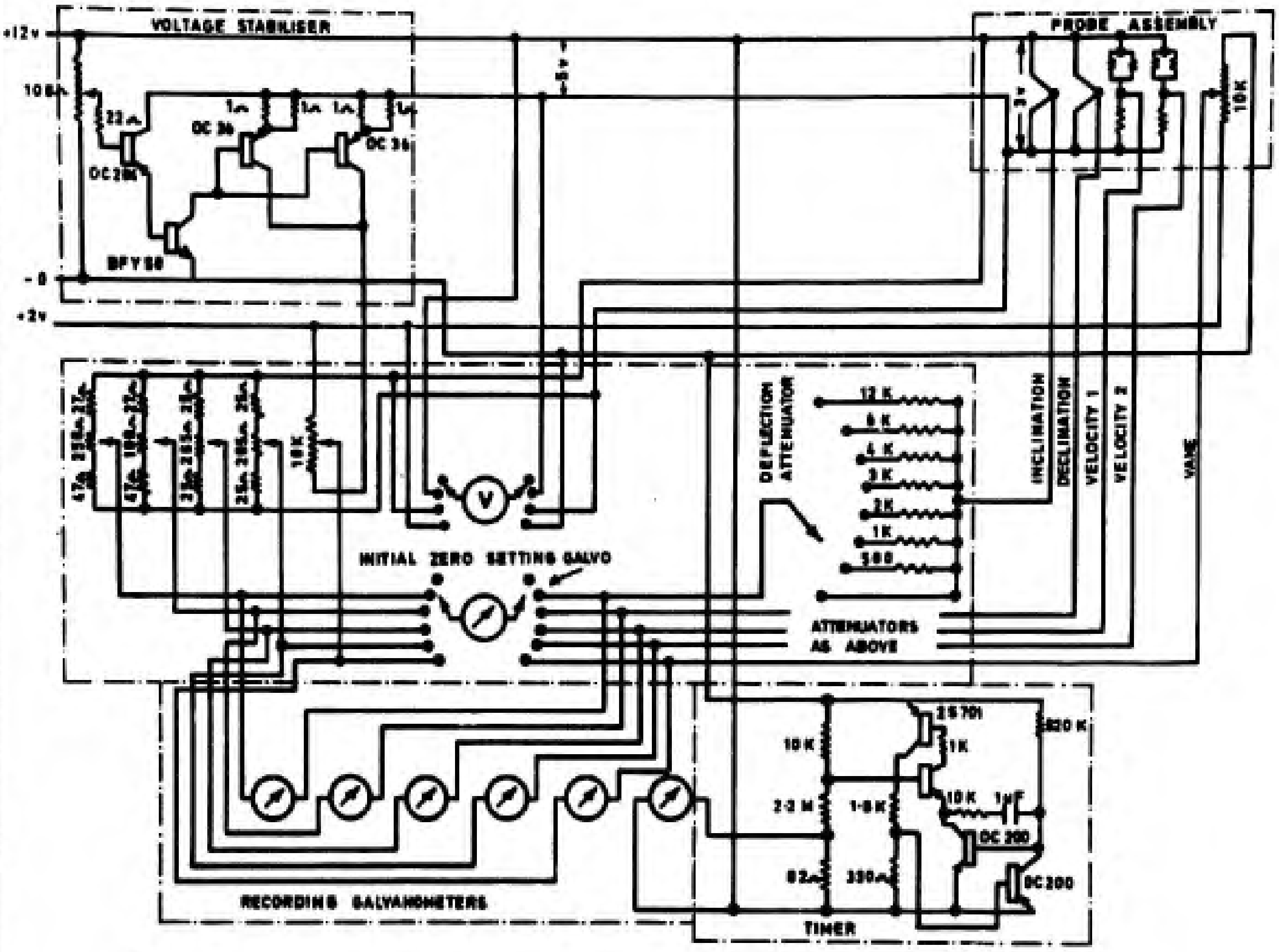


Fig.2.6. Circuit of wind speed and deflection recorder

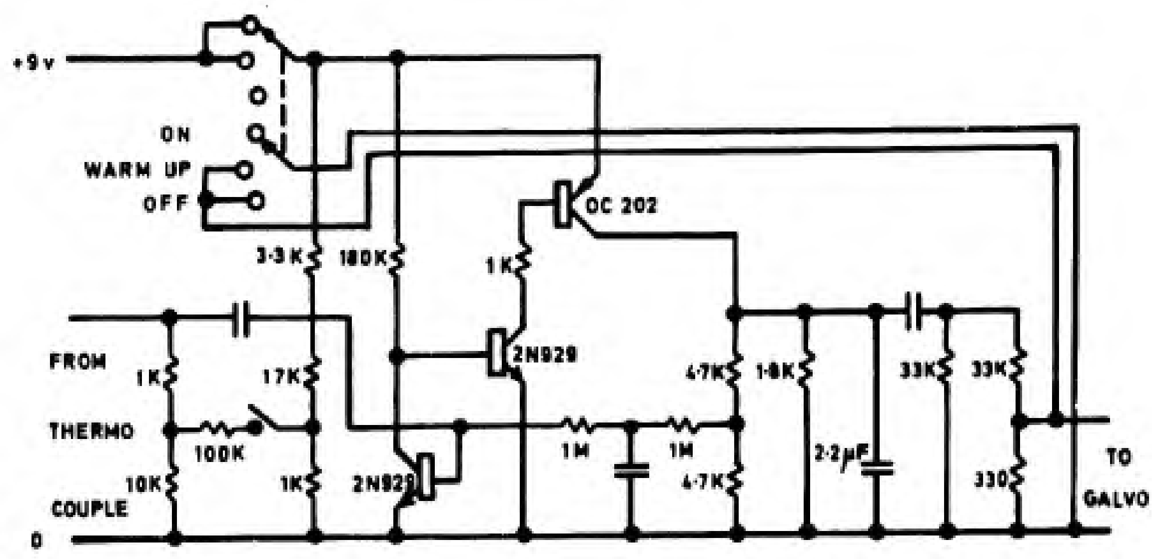


Fig.2.7. Circuit of thermocouple amplifier

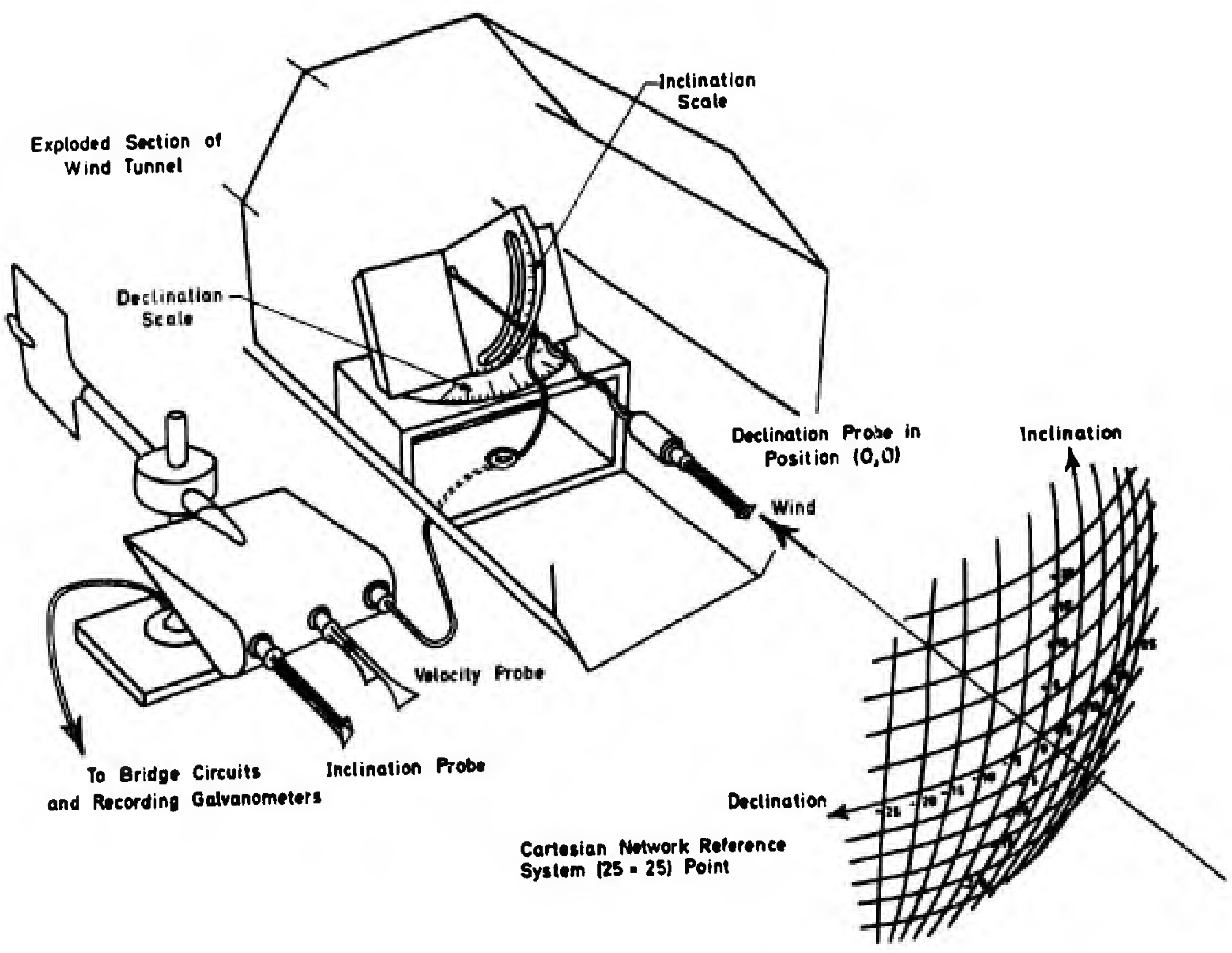


Fig.2.8. Arrangement of apparatus for probe calibration in wind tunnel

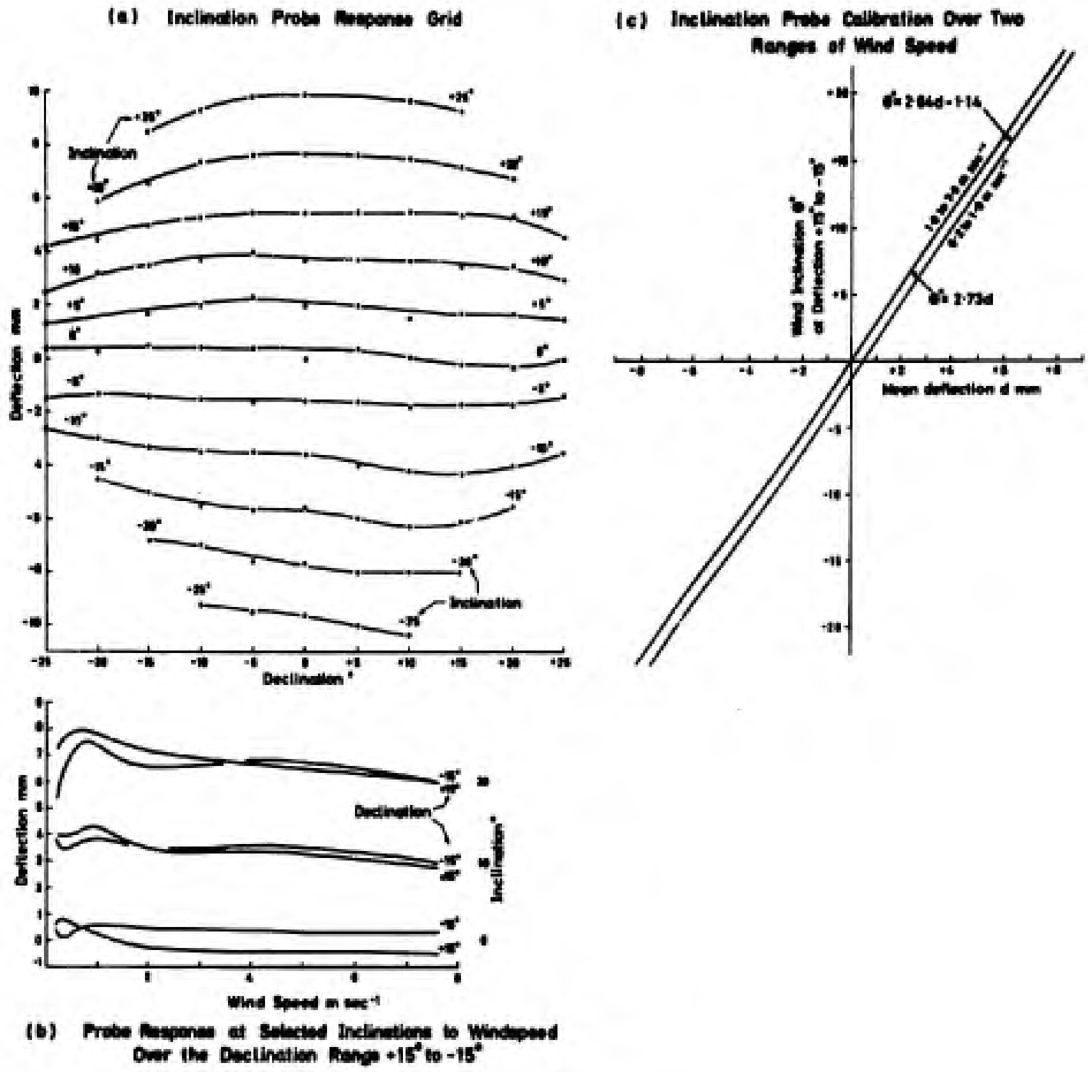


Fig.2.9. Calibration of Inclination probe

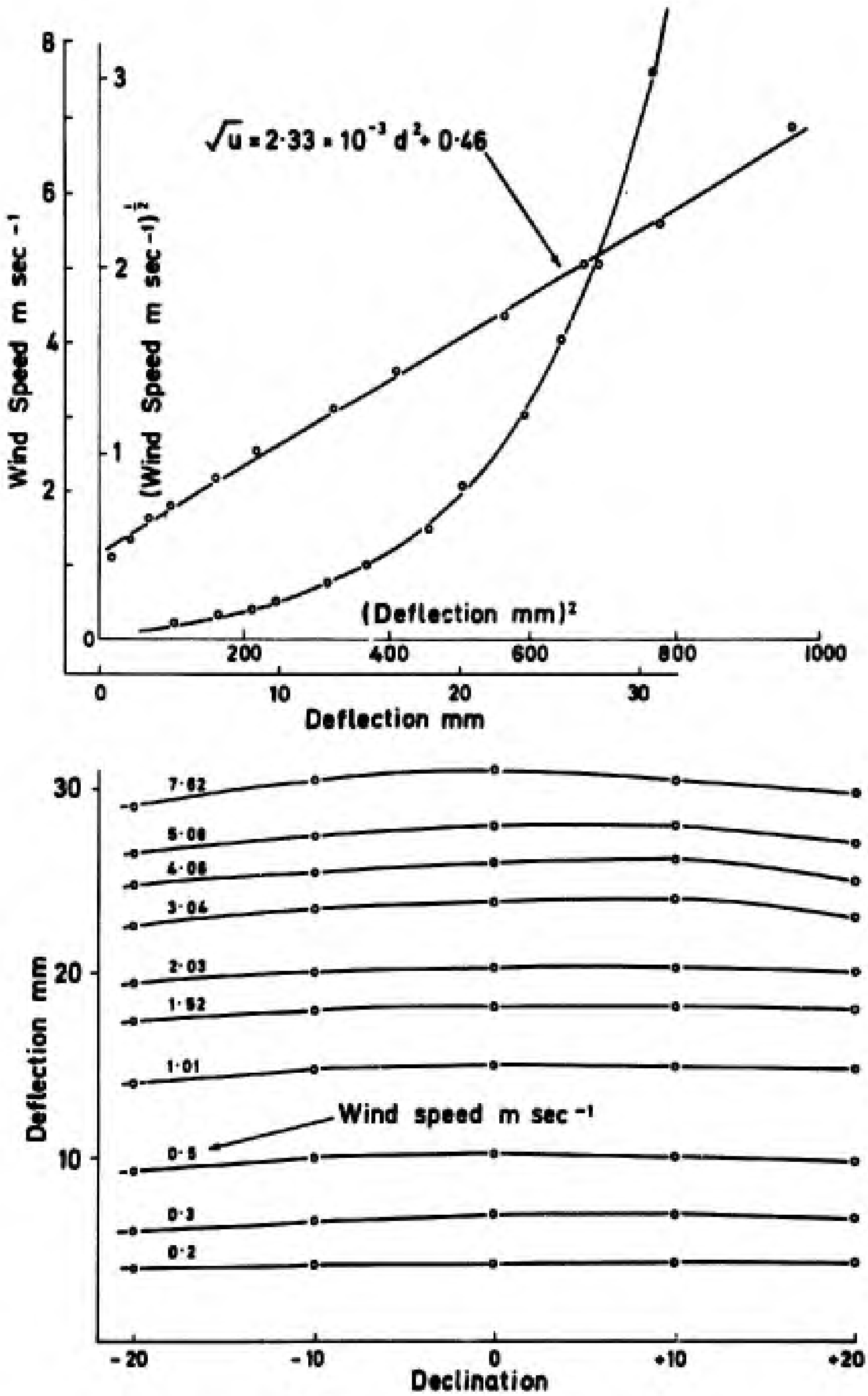


Fig.2.10. Calibration of velocity probe

above: Deflection with wind speed

below: Effect of declination

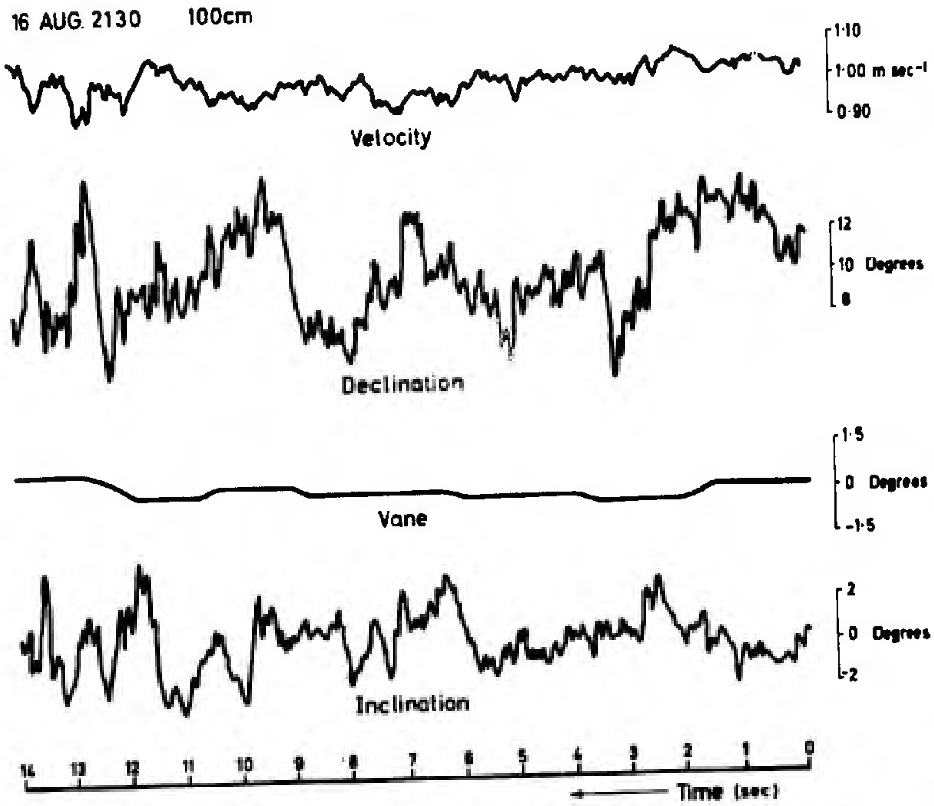


Fig.2.11. Section of chart showing recording of wind data

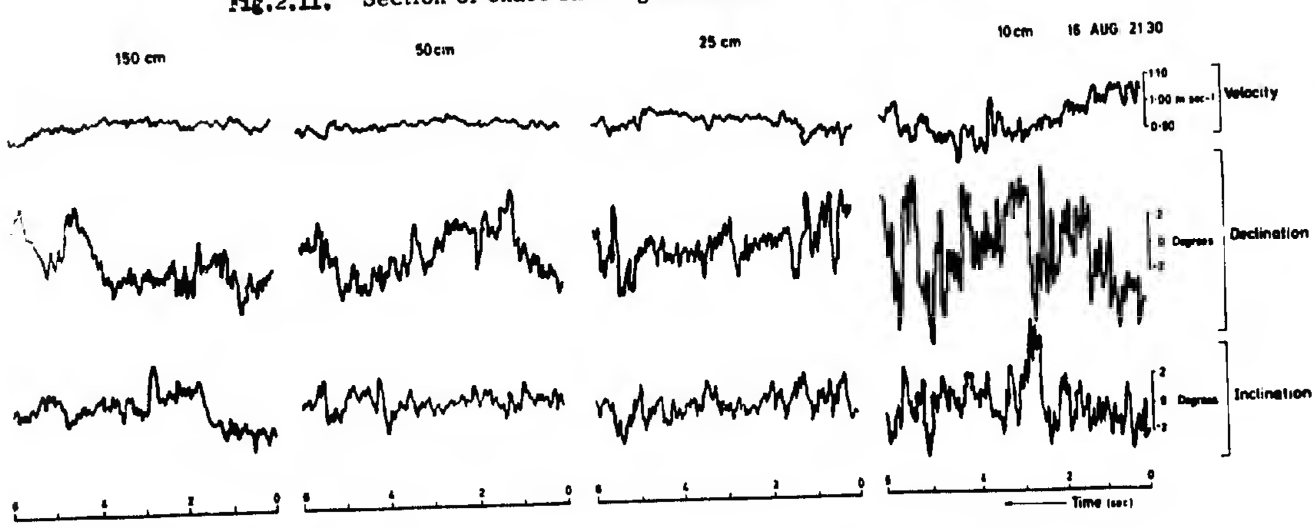


Fig.2.12. Portions of wind data chart illustrating the increase in frequency and amplitude as ground is approached

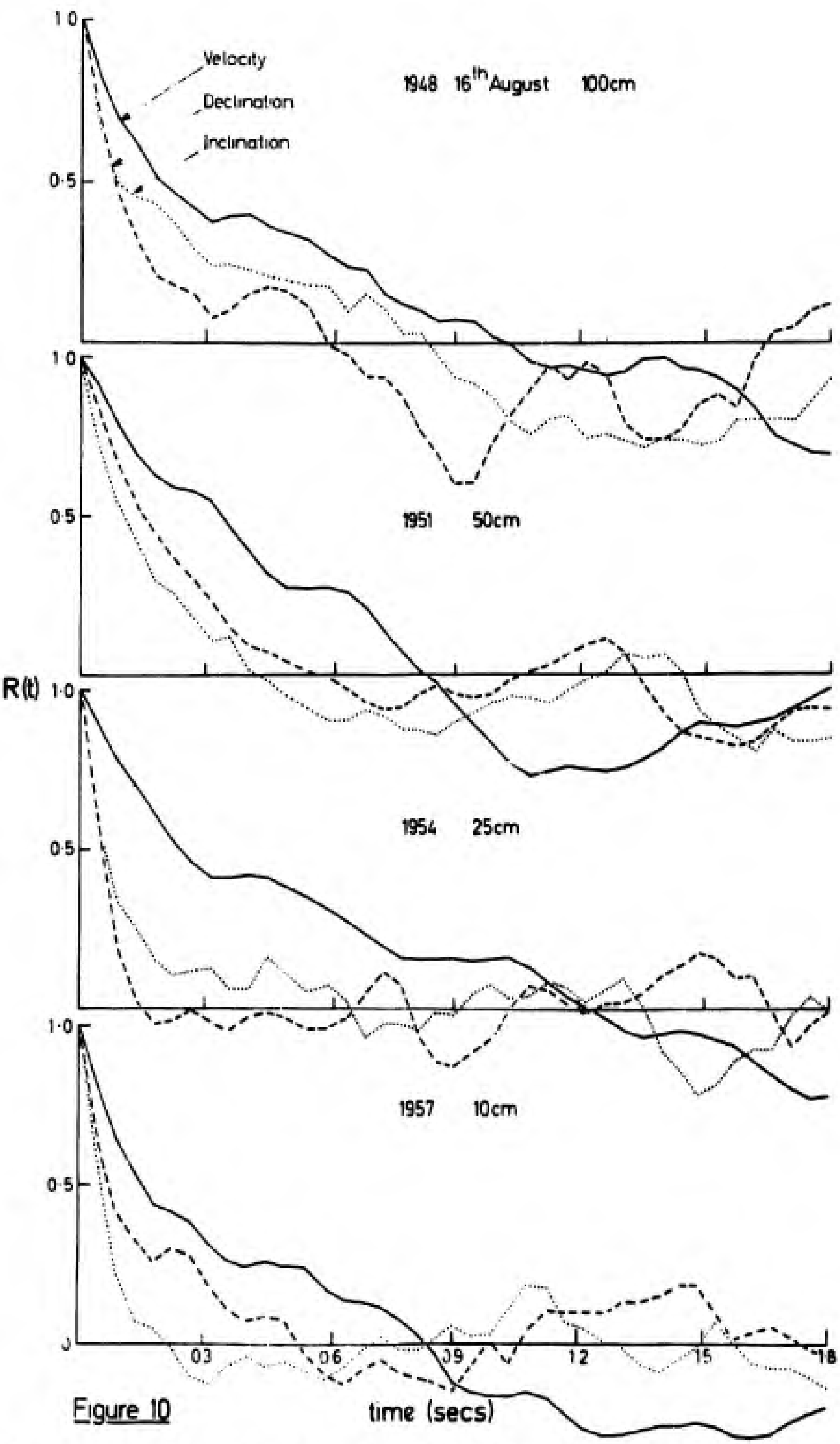


Fig.2.13. Autocorrelograms showing persistence of pattern in air flow

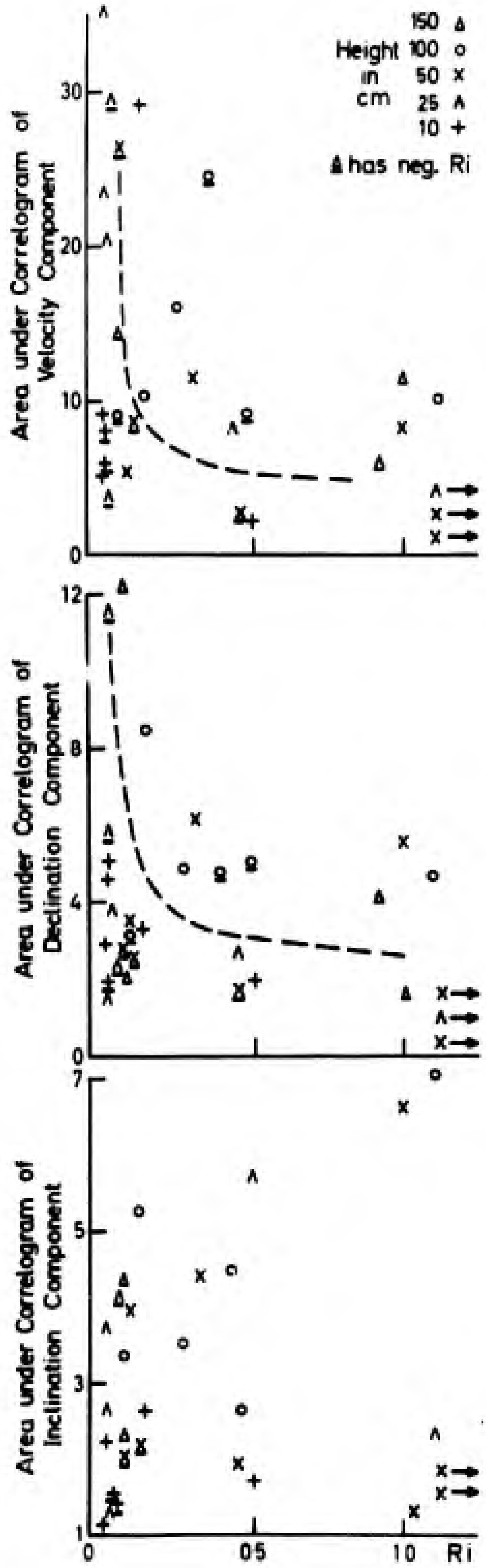


Fig.2.14. Pe rsistence of turbulence pattern with stability

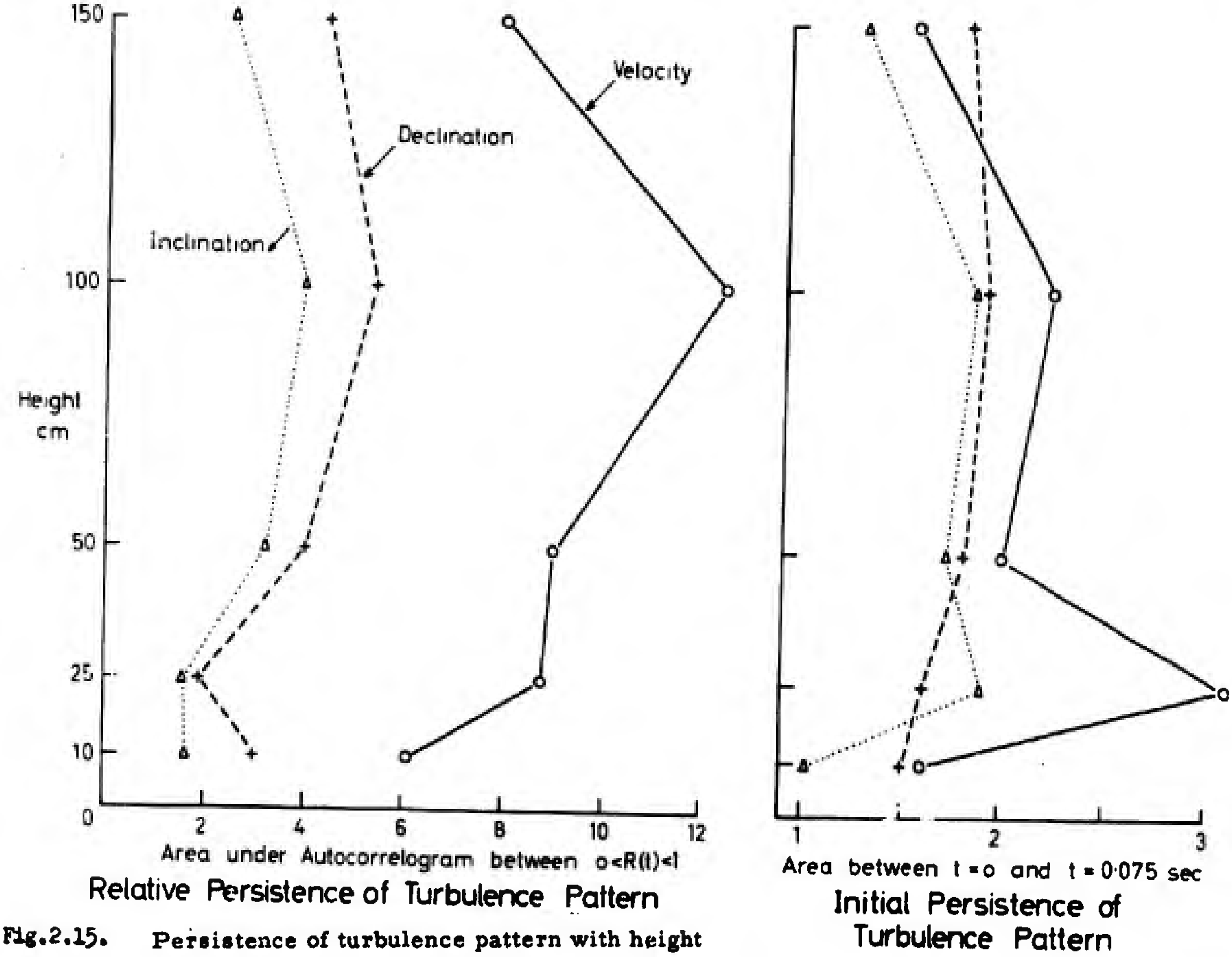


Fig.2.15. Persistence of turbulence pattern with height

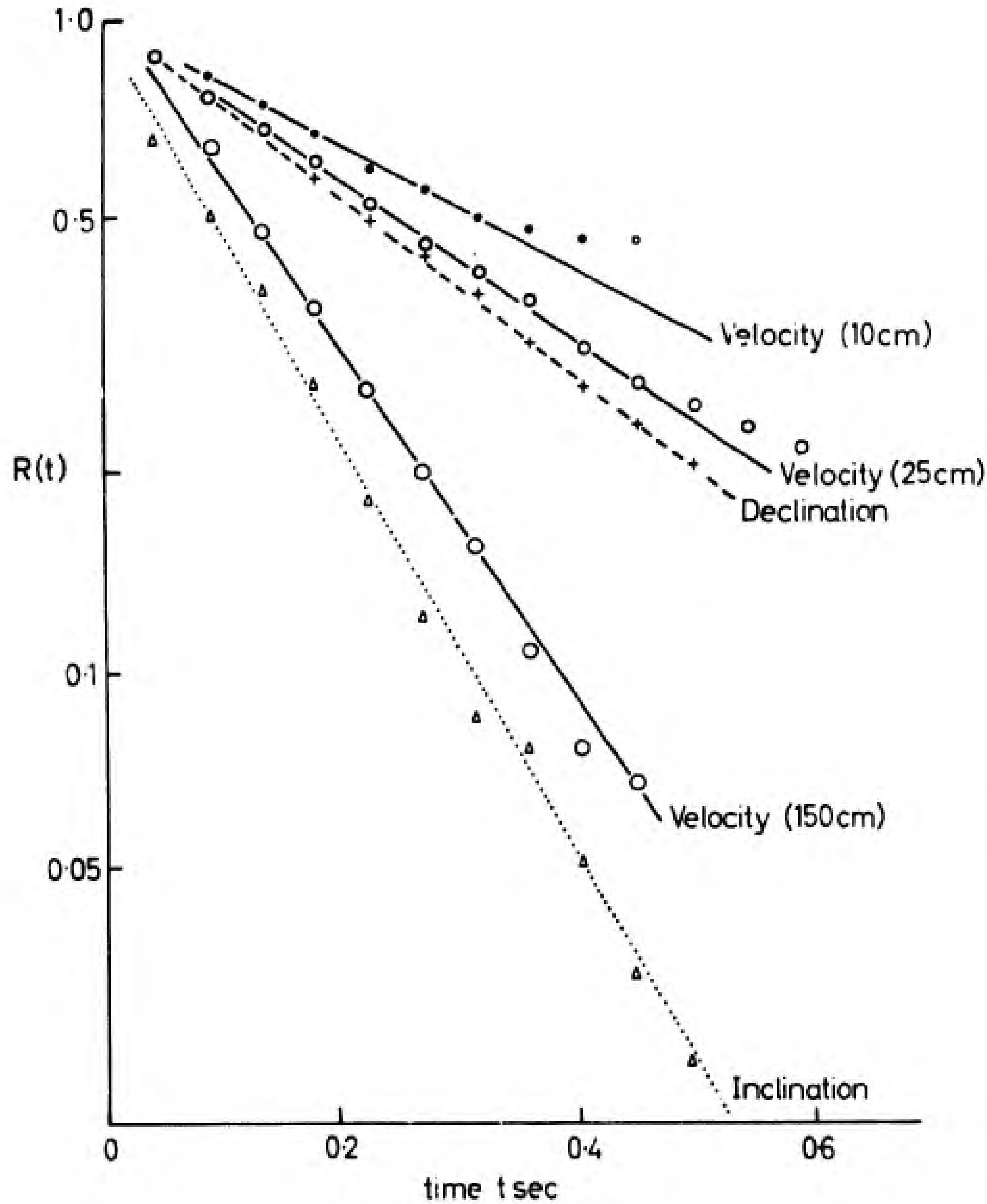
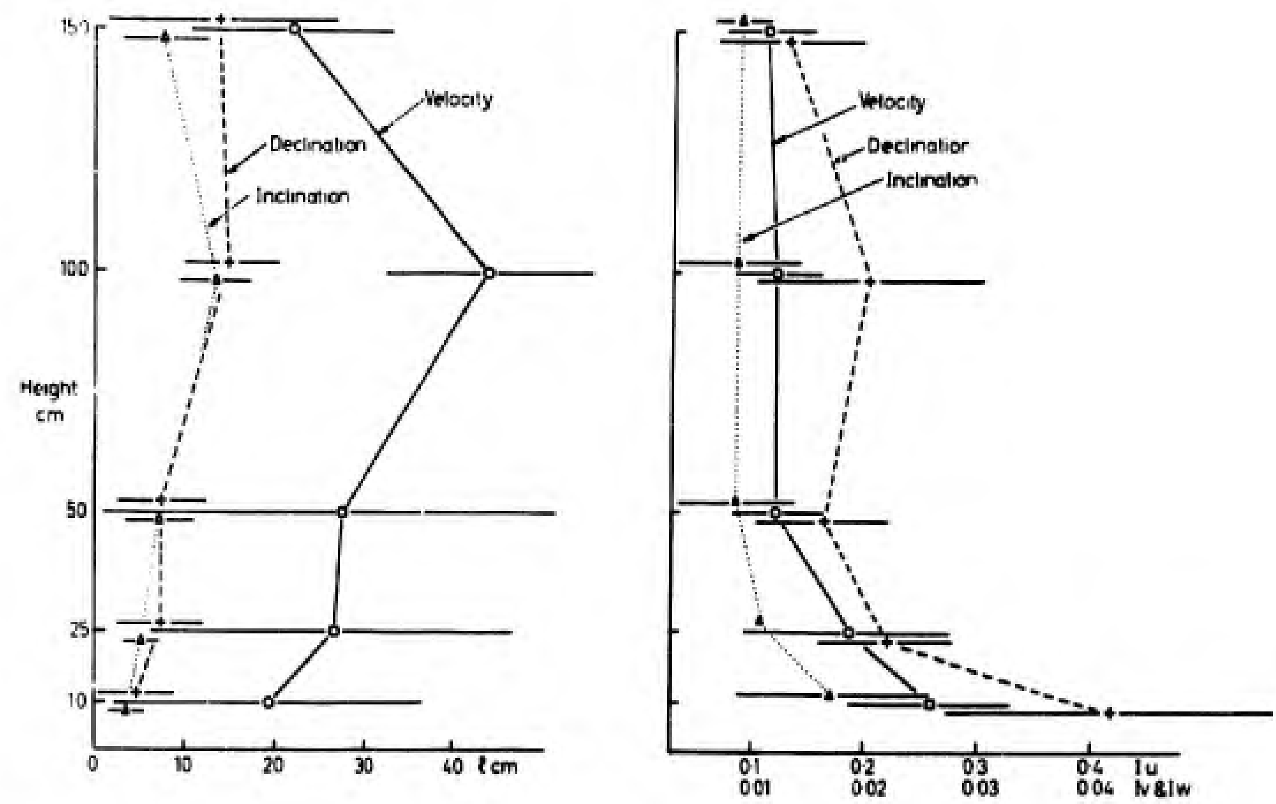


Fig.2.16. Exponential decay in autocorrelogram



Scale of turbulence $\ell = \bar{u}\int_0^\infty R(t)dt$ with height
bars show ± std. deviation

Intensity of turbulence ($Iu = \frac{\sigma_u}{\bar{u}}$) with height
bars show ± std. deviation

Fig.2.17 **Scale of tubulence with height (bars show ± std. dev.)**

Intensity of turbulence with height (Bars show ± std. dev.)

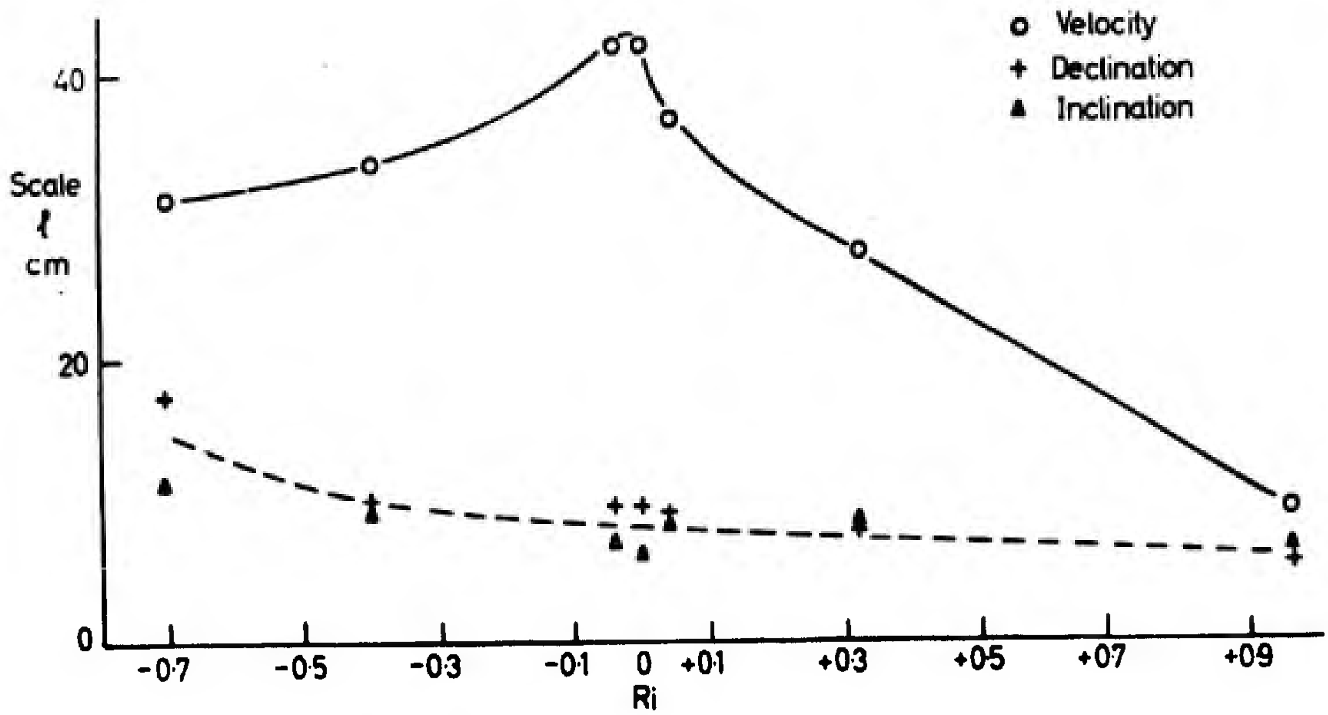


Fig.2.18. Scale of turbulence with stability

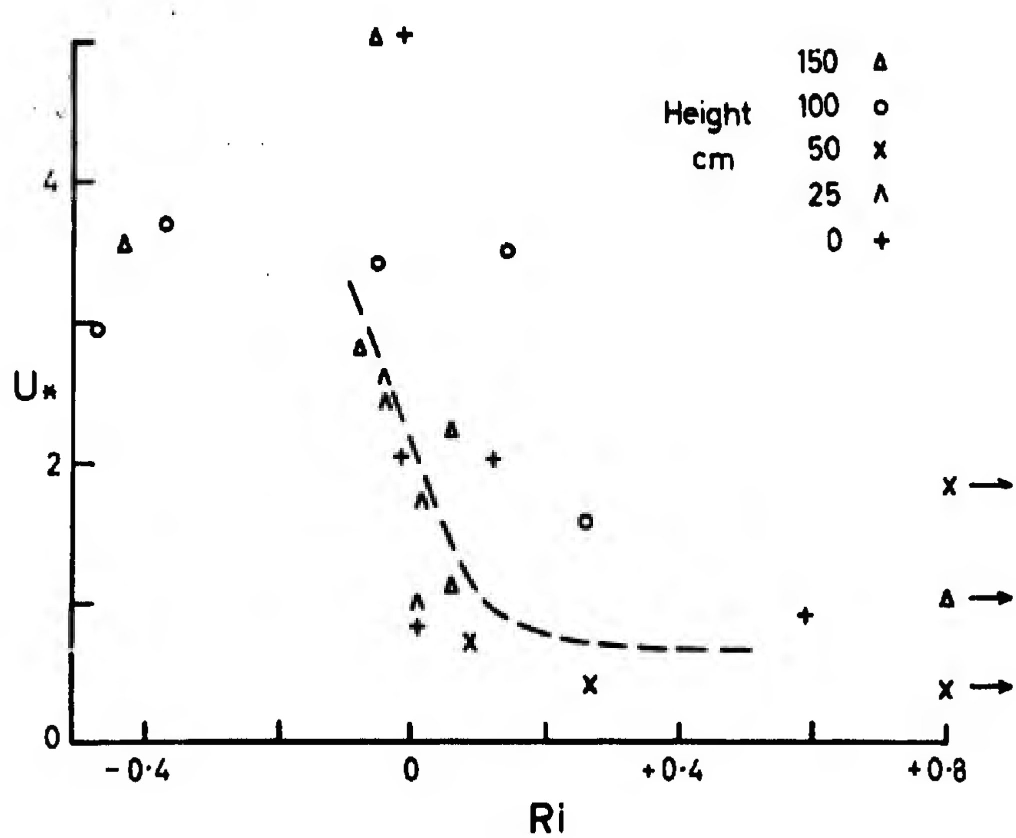


Fig.2.19 Friction velocity and stability

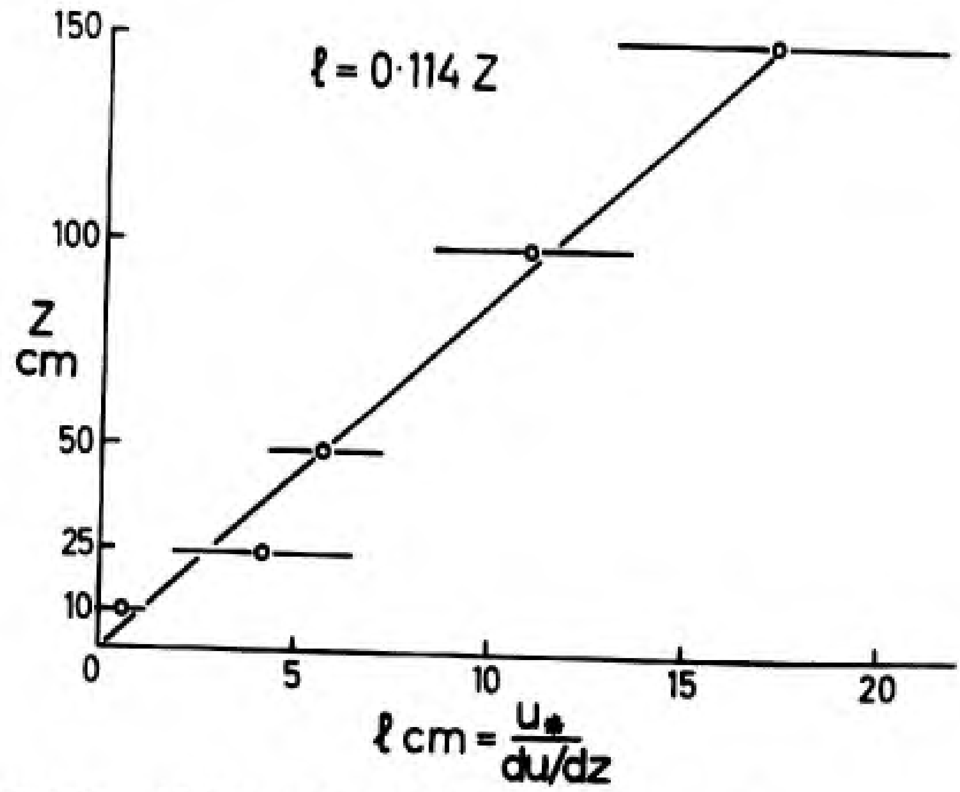


Fig.2.20 Mixing length with height (bars show $\pm$ std. error)

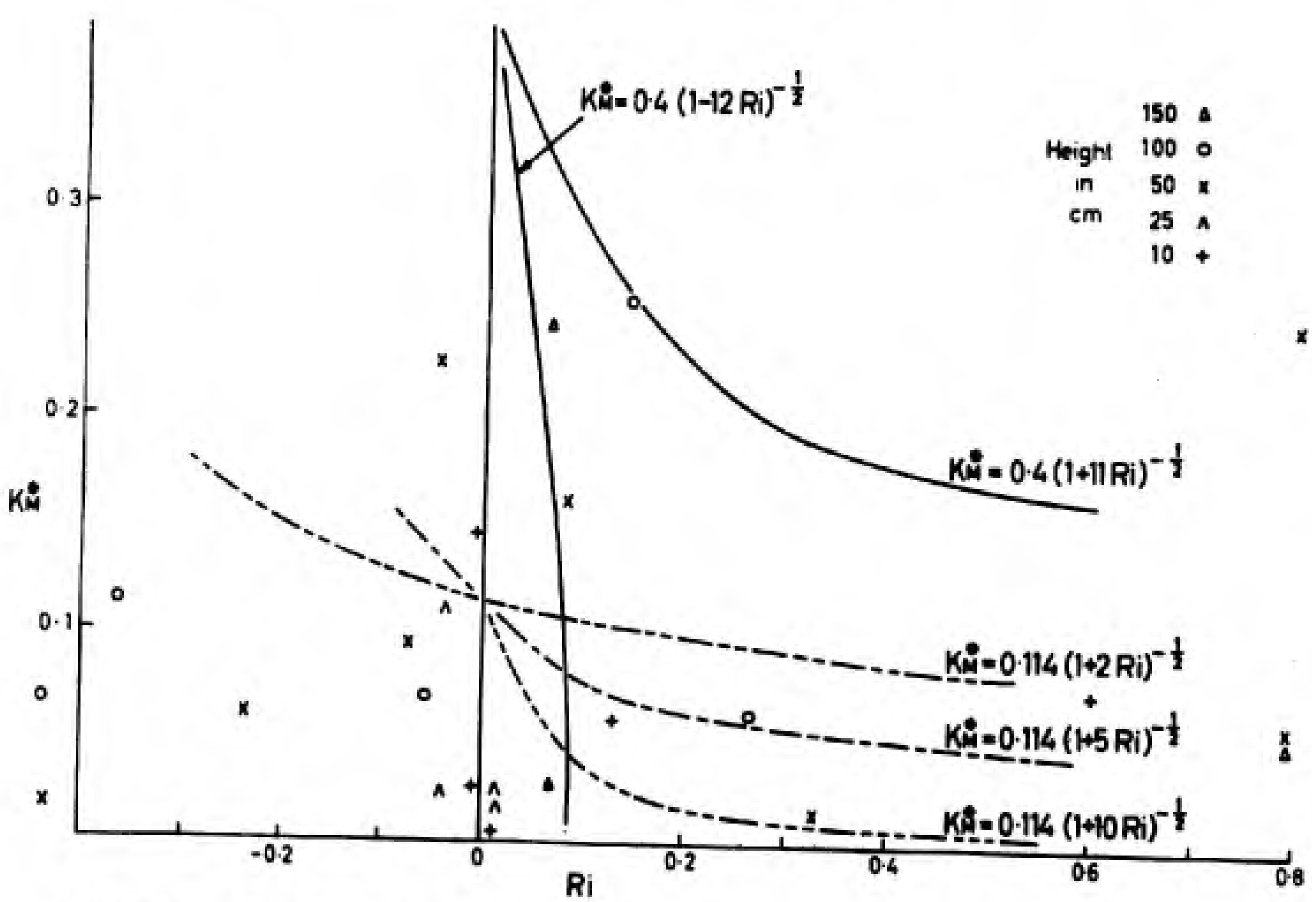


Fig.2.21. Eddy viscosity with stability

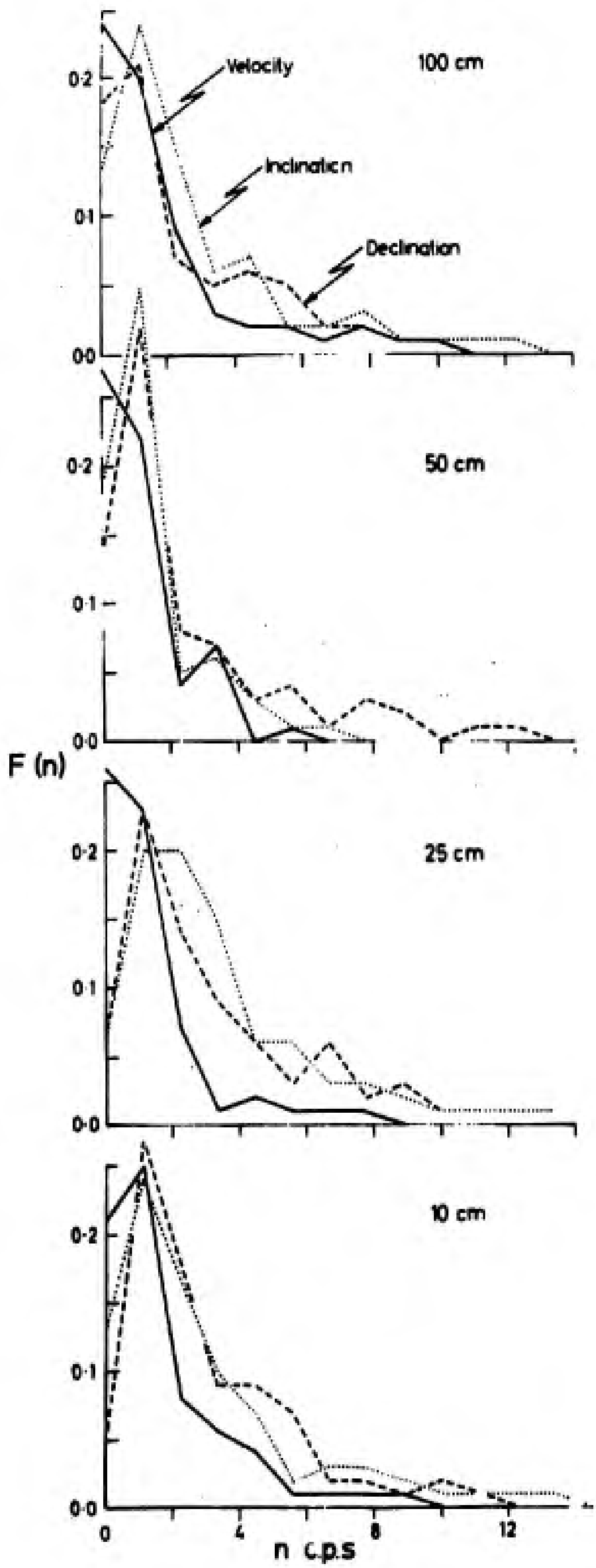


Fig.2.22. Energy spectra on linear scales (from raw data)

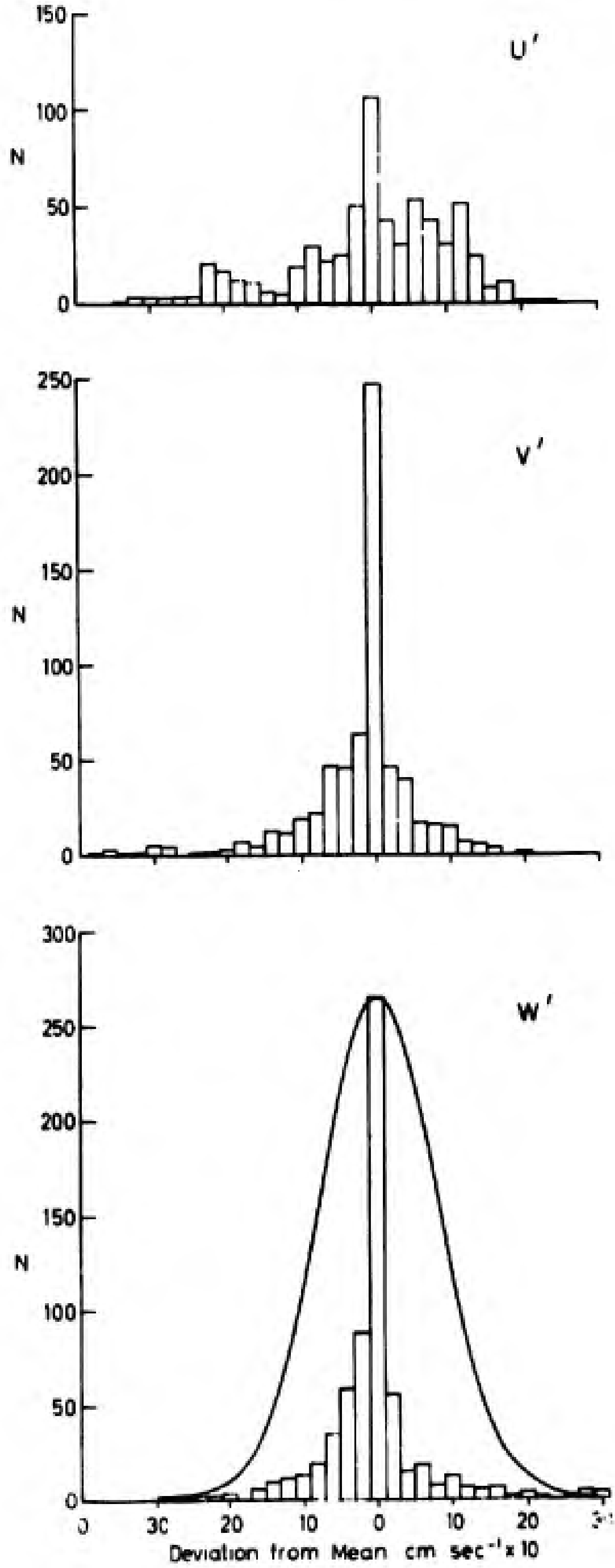


Fig.2.23. Typical frequency distribution of u, v and w components

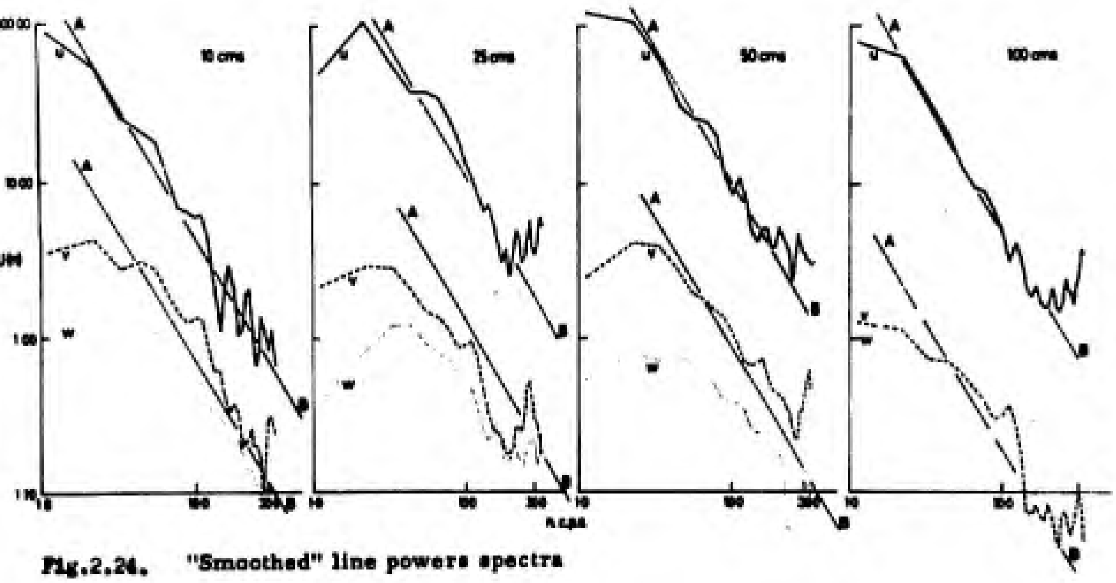


Fig.2.24. "Smoothed" line powers spectra

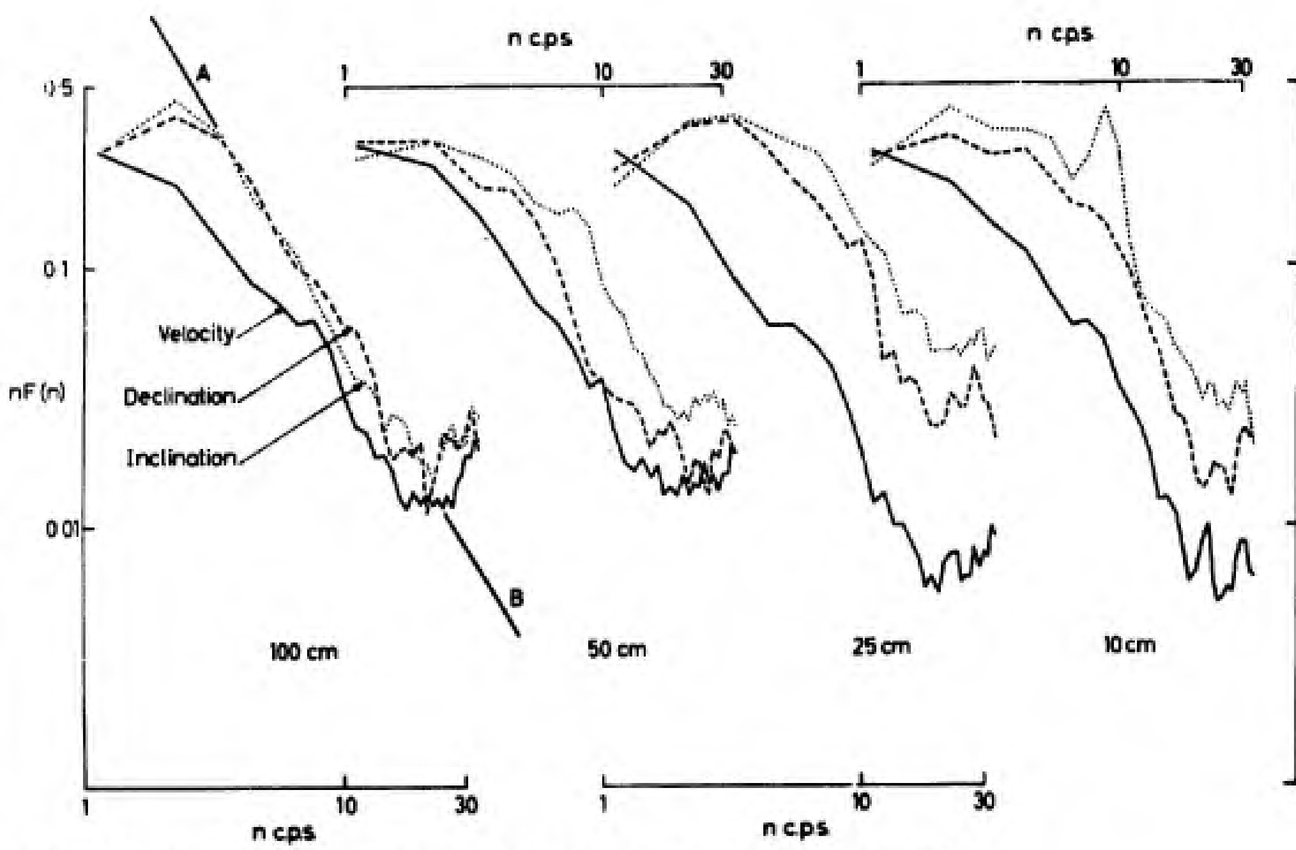


Fig.2.25. Mean energy spectra from 3 samples taken during hours 1945-2200

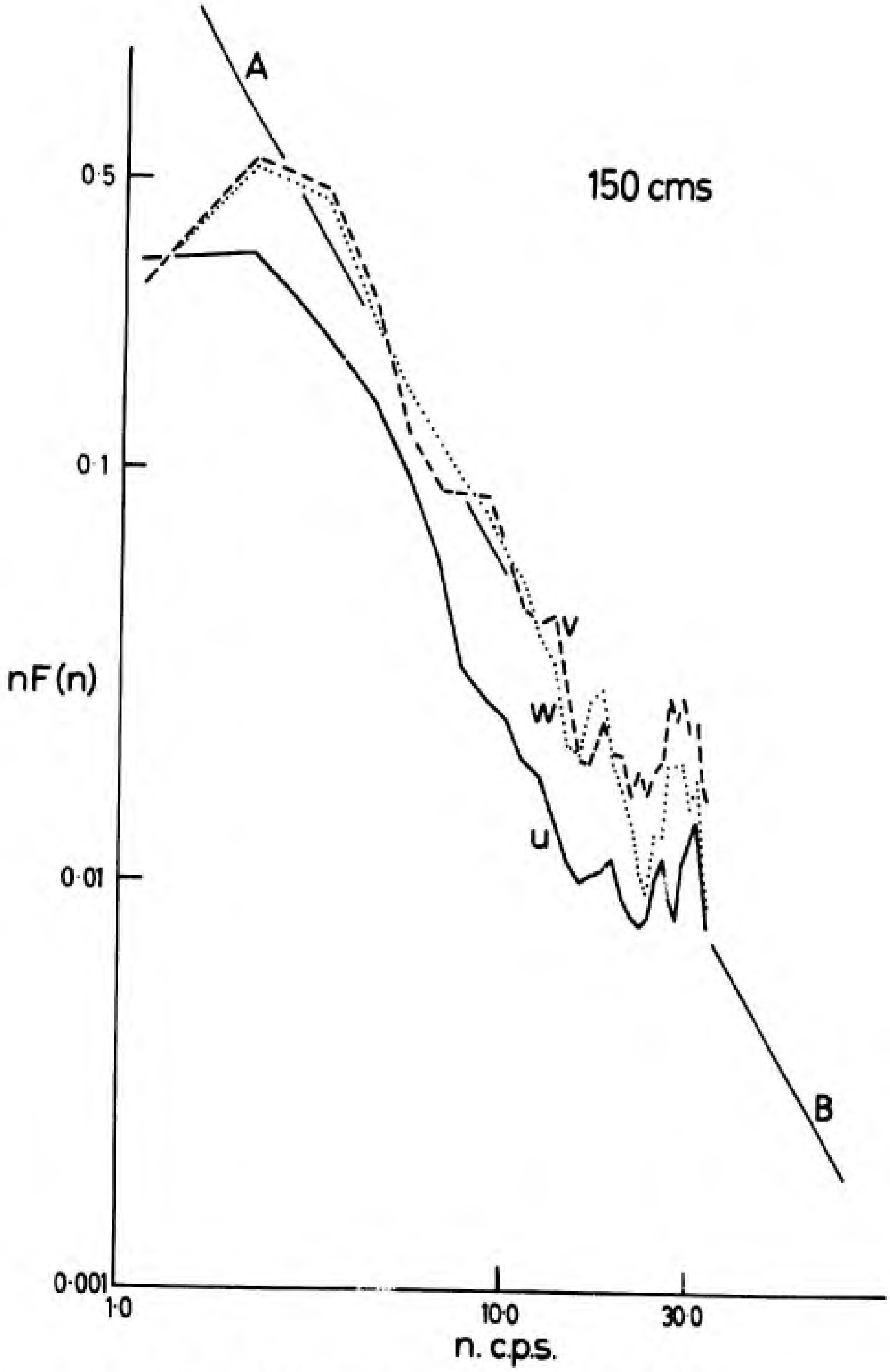


Fig.2.26. Energy spectra 2145 hours 16th Aug.

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HYDROLOGY REPORT

Hydrological Measurements on discharge from the Mir Samir West Glacier and Sediment Transport

by D.G. Jamieson

Summary

Two Gauging stations were set up on the Samir River, one near the glacier snout and one in the base camp meadow. These stations took the form of level recorders and were used to estimate the amount of water discharged from the West Samir Glacier and other surface drainage. They were calibrated from a stage/discharge curve using Sodium dichromate and a salt dilution technique. Some problems were encountered with the level recorders due to very low night temperatures (-15°C) and due to variations in the pattern of water flow at the glacier snout. Despite these problems it is estimated that the overall discharge figure of 67,885 m^3 of water is reliable to plus or minus 2%. In addition a survey was made of the sediment transported by the Samir River. It was not possible to relate this to the stage/discharge curve as the amount of sediment transported differed on the rising and falling limbs of the hydrograph. The average sediment discharge was found to be 0.0139 g/l.

Introduction

The research undertaken in Hydrology was twofold. Firstly, to combine with the glaciological programme in providing stream discharge data for the glacial melt-water for comparison with ablation rates. Secondly, to investigate the spatial and temporal distribution of suspended sediment brought down by melt-water from the glacier and surrounding snow patches.

Stream-Gauging Considerations

Both topics of research involved the measurement of stream flow. As both streams were likely to be of a juvenile nature with much turbulence, dilution techniques using sodium dichromate and sodium chloride were used. Unfortunately, the salt-dilution technique of flow measurment does not lend itself to continuous recording as it only gives an instantaneous value of discharge. Therefore, it was proposed to establish stage/discharge relationships, with the aid of two portable depth-recorders.

Principles of Salt Dilution Method

If a stream is injected with a chemical (or other tracer), a measurement of flow can be obtained by comparing the dosing concentration of the chemical with the rise in concentration at a section downstream if complete mixing has taken place. There are two main alternatives for injection.

a) Constant-rate injection

When dosing is continued at a constant rate the rise in concentration of the chemical at the downstream section is observed to reach a constant value

If Q = rate of flow of stream
q = rate of injection of tracer
Co = original concentration of dosing solution
C_1 = naturally occurring concentration of tracer in stream water
C_2 = concentration of tracer at sampling point

then

$$q.Co + Q.C_1 = (Q+q)C_2$$

$$Q = \frac{(Co-C_2)q}{(C_2-C_1)} \quad \ldots\ldots\ldots (1)$$

Since Co is much greater than C_2, equation (1) can be simplified to

$$Q = \frac{Co}{C_2-C_1}q \quad \ldots\ldots\ldots (2)$$

In the special case of sodium dichromate, the naturally occurring or background concentration is generally nil. Thence equation (2) can be further simplified to

$$Q = \frac{Co\ q}{C_2} \quad \ldots\ldots\ldots (3)$$

b) Sudden injection

If a known volume, V, of tracer solution is deposited rapidly in the stream, the resulting time/concentration curve at the downstream section can be integrated to find the stream discharge

$$(Co - C_1)V = Q\ (C_2 - C_1)dt$$

hence

$$Q = V\frac{Co}{(C_2 - C_1)dt} \quad \ldots\ldots (4)$$

Colorimetric Method of Flow Measurement

In chemical analysis, the use of reagents for producing a characteristic colour denoting the presence of an element or compound is well known. Some reagents display the additional property of producing a light intensity proportional to the amount of chemical present. This technique is of particular use for measuring small concentrations of tracers. If the salt and appropriate reagent are to be considered suitable for dilution techniques of flow gauging, then the resulting coloured solution must conform with Lambert's and Beer's Laws.

Lambert's Law

The intensity of light passing through a liquid decreases inversely with the depth of liquid providing the quality of light remains constant.

Beer's Law

The absorption of monochromatic light by a solution is proportional to the concentration of the ions in solution.

One such salt and reagent used in dilution techniques is sodium dichromate $Na_2Cr_2O .2H_2O$. A photo-electric colorimeter can be used to measure the optical density of its reaction with diphenylcarbazide $(C_6H_5NH.NH)_2$ Co, the magenta colour being proportional to the amount of chromate present.

Natural waters seldom contain chromium ions in solution. In addition, colorimetric analysis permits the measurement of very low concentrations of sodium dichromate. Consequently, the amount of salt required is small - a critical factor on expeditions. Colorimetry has the additional advantage over its competitor, conductivity, of being unaffected by temperature.

However, the cost per gauging is considerably increased by using sodium dichromate. Consider a hypothetical gauging of the Samir river, the total injection time being twelve minutes and the supposed discharge fifty cusecs.

	Constant rate injection sodium dichromate	Constant-rate injection NaCl Conductivity	Sudden injection NaCl Conductivity
Wt. of salt required	1,000g	8,500g	6,800g
Cost of salt per lb	2 - 0d	1d	1d
Cost of salt per gauging	4 - 5d	1 - 7d	1 - 3d

With regard to toxicity, there is no danger to fish at the concentrations used for accurate gauging i.e. 0.5 to 0.75 p.p.m. However, at this concentration, there is evidence to suggest that plankton may be affected if subjected for prolonged periods. Although sodium dichromate has no reaction with natural water it is reduced by reducing agents found in polluted waters. The difficulties implied by these last two statements should not be emphasized since firstly, no injection would last more than thirty minutes so no serious consequences would arise with plankton and secondly, glacial melt-water is hardly likely to be polluted. Stability of the chemical is very good but if samples have to be kept for more than a week before analysis, then they should be stored in darkness.

Conductivity

The conductivity method of flow gauging was only intended to be an auxiliary method for use in emergencies. However, it was used to give the pulse characteristics of the mixing length. By tipping in an arbitrary quantity of 3/4 saturated NaCl solution at the proposed dosing point and measuring conductivity at the selected sampling point, the characteristic time/concentration curve can be constructed. Time to start sampling in the event of gauging by constant-rate injection is given by the time where the sudden-injection curve reverts to the background concentration.

Stream temperature was measured with the aid of a thermistor bridge.

Depth of Flow Measurement

As has been stated previously, it was intended to use salt- dilution techniques only as a means to calibrate level-recorders situated on the glacier stream and the Samir River.

Samir River

A portable Lea level-recorder, with a horizontal drum and natural height scale was used for the Samir River. The recorder was mounted on a folding stilling-well made from aluminium sheeting and located in a slow-moving reach of the river close to base-camp. No artificial control-section was necessary. Although during most nights, the stream temperature was around $0^{\circ}C$ no difficulty was experienced with freezing.

An excellent mixing reach existed where the river plunged over a rock outcrop, into a narrow gorge in a series of waterfalls.

Glacier Stream

A portable Munro level-recorder was installed to measure the depth of melt-water at the snout of the glacier. No ideal site was available. The stream flowed down the western edge of the glacier, only to be joined by seeping water from two semi-frozen lakes which had formed between the snout of the glacier and terminal moraine. For a brief stretch, all the melt-water formed a stream before dispersing between boulders to pass through the moraine. The flow on its re-appearance could no longer be called a stream, as it was no more than a general seepage.

However, on our arrival, several feet of snow had forced the melt-water into some semblance of a channel. Originally the level-recorder was installed upstream of an artificial control section built of boulders. This had the effect of reducing the stream velocity sufficiently to install a similar stilling-well to that on the Samir River. It was necessary to terminate the control section on solid rock so that the depth of water resulting was in no way affected by the presence of snow, otherwise a stable regime could never have been achieved.

With the melting of the snow, however, it became apparent that the site chosen was not suitable as the melt-water found its way under the snow and by-passed the control section. Indeed, by the end of our stay, this section had been left high and dry. In addition, it was possible to have an increase in depth recorded with a decrease in discharge. During the night, ground temperatures often dropped to around -15°C. With such low temperatures, ice formed on the stone barrage erected to decrease the water velocity, thus reducing the permeability. Although the discharge was decreasing during the night, the water-level was rising forming ice crystals. With the surface layer continually freezing, the water flowed along the surface until in turn it was frozen also. The apparent water level was thus raised some six inches and recorded by the float until that too was frozen solid.

With the ablation of the snow cover it was possible to select a second site which avoided some of the above difficulties. No attempt was made to form a stilling pool with stones, indeed some were removed so that all stones in the channel were below the minimum water level. The channel was deepened to accommodate all the melt-water, care being taken to ensure there was no likelihood of water finding a new channel with further recession of the snow cover.

Although the freezing of the stilling-well at night was delayed by adding paraffin, it still froze beneath this layer. Soaping the float had little effect. Additional precautions included a screw gauge fixed to the side of the stilling-well to check the recorder had not moved with ice or water pressure.

Selection of Gauging Reach

Dilution gauging is dependent on thorough mixing of concentrated solution with stream water before the sampling section. Consequently, the choice of reach and length of stream required is of great importance. Two empirical formulae have been suggested to predict the minimum mixing length, both of them are of little use.

HULL (1962)

$$L\ min = 50Q^{1/3} \quad (Q \text{ in cusecs})$$

RIMMAR (1952)

$$L\ min = 0.13C \left(\frac{0.7c + 11}{g}\right) \frac{b^2}{h} \qquad (\text{F.P.S. units})$$

C	=	Chezy coefficient of roughness
b	=	average width of stream
h	=	average depth of water
g	=	gravitational constant

Neither formula takes into account the cause of the mixing i.e. the dissipation of energy due to the difference in head between the two sections.

In the case of the Samir River an excellent mixing reach existed where the river plunged into a narrow gorge. Prior to this the river had meandered its way across a flat meadow. According to Hull's formula, the mixing length for both reaches would be the same. Rimmar's formula does try to take into account a measure of channel roughness in the form of Chezy C but this is only applicable for uniform flow and if the flow is uniform then the reach is not suitable for dilution gauging.

Consequently, it is necessary to rely on ones own personal judgement based on previous experience. No difficulty was experienced with the Samir River but a precaution against incomplete mixing at the sampling section, samples were taken simultaneously at both banks. The glacier stream was more difficult owing to the extremely short mixing length available. Boulders were placed in the stream at strategic points to help the dispersion of the concentrated solution. After gauging, these were removed because of the difficulty with freezing previously mentioned. Sampling was carried out at both banks and centre of stream.

Method of Obtaining Constant-Rate Injection

A simple apparatus that will yield a steady discharge, despite a varying water level is generally known as a Mariotte vessel. It consists of an air-tight receptacle having an interchangeable orifice at its base and an air pipe projecting downwards through the top. After the vessel has been filled with the concentrated solution and the filling-plug closed, the fall in surface level as the liquid escapes through the orifice will soon lower the pressure of the residual air to the point at which atmospheric air enters by the air-pipe and bubbles up through the liquid.

Gauging Procedure:- Sodium Dichromate

From a prior NaCl gulp injection, the total pulse time had been determined. To this is added the time required for sampling which in this case was four samples either banks at 2-minute intervals making a total of six minutes. A 30-litre Mariotte vessel was used for discharging the solution. From Table 3.1. a suitable nozzle was selected to give an emptying time in excess of the total required injection time.

Nozzle	Open Pipe	0.164"	0.125"	0.110"	0.106"	0.096"
Max. injection time (mins)	12	18	30	37	46	52
9 litre/min	2.25	1.48	0.88	0.73	0.58	0.52

Table 3.1.

Concentration of chromate p.p.m.	Required dosing rate q (litre/min) for Q (cusec.)											
	250 g made up to 30 litres						500 g made up to 30 litres					
	5 cusec	10 cusec	15 cusec	20 cusec	25 cusec	30 cusec	5 cusec	10 cusec	15 cusec	20 cusec	25 cusec	30 cusec
0.125	0.18	0.35	0.53	0.70	0.88	1.06	0.09	0.18	0.26	0.35	0.44	0.53
0.250	0.35	0.70	1.05	1.41	1.70	2.11	0.18	0.35	0.53	0.70	0.88	1.05
0.375	0.53	1.05	1.58	2.11			0.26	0.53	0.79	1.05	1.32	1.58
0.500	0.70	1.40	2.11				0.35	0.70	1.05	1.40	1.76	2.11
0.625	0.88	1.76					0.44	0.88	1.32	1.76	2.20	
0.750	1.05	2.11					0.53	1.05	1.58	2.11		
0.875	1.23						0.62	1.23	1.84			
1.000	1.40						0.70	1.40	2.10			
1.125	1.58						0.79	1.58				
1.250	1.75						0.88	1.75				
1.500	2.10						1.06	2.10				

Table 3.2.

A rough estimate of the stream discharge is necessary so that the required amount of salt can be selected from Table 3.2., knowing the selected nozzle's rate of discharge, and the estimated stream discharge, to give a rise in chromate of 0.5 to 0.75 p.p.m.

The required weight of sodium dichromate crystals was dissolved and made up to 30 litres in the vessel using stream water. Complete mixing of the concentrated salt solution was essential. After discharging a small amount of salt solution, the first concentrated sample S1, was taken for serial dilution.

Once the Mariotte vessel had begun injection, the time taken to discharge each successive litre was measured with a stop-watch. After the gulp-injection pulse time had elapsed, 4 samples were taken downstream at both banks at 2 minute intervals. Once the last downstream sample had been taken, a second concentrated-solution sample, S2, was taken.

Unfortunately, these techniques for measuring minute quantities of chromate are not suitable for measuring the chromate concentrations of the stock solution. Consequently, it is necessary to dilute the stock samples by a known amount until the concentration is similar to that of the downstream samples.

Exactly 1 litre of stream water, taken upstream of the dosing point and therefore containing no dichromate, was put into each of six 40-oz polythene bottles, A1, A2, B1, B2, B3, B4. Using the estimated stream discharge and the actual Mariotte vessel discharge rate, the stream dilution was estimated from 1

$$\text{stream dilution} = \frac{1700 \times \text{est. stream discharge (cusecs)}}{\text{Rate of discharge of stock sol. (litre/min)}}$$

Rather than use pipettes which were susceptible to breakage, two modified hypodermic syringes were used in the serial dilution. These syringes were extremely accurate and had been previously calibrated. Table 3.3. gives the syringe sizes to give the required dilution ratio which should approximate to the stream dilution.

Approximate Serial Dilution

Syringe size (ml)	4	5	6	8	10
4	63,000	50,500	42,100	31,600	25,400
5		40,400	33,700	25,400	20,300
6			28,100	21,100	16,900
7				15,900	12,700
8					10,200
10					

Table 3.3.

Using one of the syringes, the same amounts of S1 and S2 were introduced into A1 and A2 respectively. After thorough shaking of A1 and A2, a second syringe was used to dispense the complementary amounts of A1 into B1 and B2 and A2 into B3 and B4 so that B1, B2, B3 and B4 should be of the same chromate concentration.

To 50 ml of each downstream sample and secondary dilution sample was added 2 ml of diphenylcarbozide and 10 drops of conc. sulphuric acid which hastens the formation of the magenta colour. A 50 ml sample of uncontaminated stream water is treated in a similar manner to form a standard of 0 p.p.m. The optical density of each sample was in turn compared with the standard using a Unicam Sp 1300 colorimeter with correct filter. The resulting log. deflection had already been calibrated in the laboratory. The means of the downstream values, C_2, and serial dilution samples, C_3, were used to calculate the stream discharge from:-

$$Q \text{ (cusecs)} = 0.0005866 \times q \text{ (litres/min)} \times \frac{C_3}{C_2} \times \text{dilution ratio}$$

and plotting this against the corresponding stage, built up a stage/discharge relationship. (figs. 3.1. and 3.2.).

Hydrograph Shape

It is of some interest to compare the hydrograph shapes of the Glacier stream and the Samir River even if only qualitatively.

Glacier Stream

Despite a severe drop in temperature during the night, the glacier stream never stopped flowing (Fig. 3.3.). The diurnal variation in flow is not so evident as that for the Samir river. Minimum flow occurred at 10 a.m. each day and the discharge slowly responded to incoming radiation until maximum discharge occurred, generally about 6 p.m. After this flow decreased but the response to the sharp drop in temperature is tardy. It is as if the glacier acts as a large reservoir with a slow response. During the night, three feet of firm snow acted as an insulation barrier protecting the percolation of water along the surface of the ice. Several cloudless days had to precede the higher discharges while the flow gradually built up.

Samir River

The diurnal variation of discharge was very pronounced with maximum daily flow almost double that of minimum (Fig. 3.4.). It would have been greater except for channel storage and reservoir action which was prevalent in the base-camp meadow. Minimum flow occurred at about 12 noon and maximum at 9 p.m. A similar reservoir action to that of the glacier was noticeable, suggesting that the snow cover was of sufficient depth to insulate the melt-water and keep it from freezing at night. The pattern of flow in the Samir River was similar to the pattern of day-time temperatures (Fig. 3.5.).

Conclusion

During the period that measurements of discharge were made on the Glacier Stream some 67,885 cubic metres of water appeared in the form of melt-water (fig. 3.6.). During the same period, an estimated 69,176 cubic metres of water was ablated from the surface of the glacier suggesting that little or no water was lost by evaporation. However, it should be realised that the relative precision of the various measurements in the water balance was not equal. The measurement of discharge, despite difficult gauging conditions, was probably within ± 2 percent; ablation was estimated from the simple arithmetic mean of nine stakes spaced over the surface of the glacier. No perceptible change of density of the remaining firm snow was evident and the water - equivalent remained remarkably constant over the whole surface. Probably the greatest source of error was the measurement of the area of the glacier which terminated on two sides in a near vertical wall of snow.

However, the conclusion is reached that only a very small percentage of the ablated surface is evaporated but the exact proportion would have to be determined from observations over a far longer period with emphasis on measuring ablation with a greater degree of accuracy.

Alluvial Hydraulics

The temporal variation of silt in suspension was investigated in the Samir river. A single sample was taken at 60 per cent depth below the surface near mid-stream at hourly intervals for two periods of 24 hours each. Sampling was effected by hand using a wide-necked 3/4 litre polythene bottle. The Oxoid membrane filters were used to remove the silt with the aid of a vacuum pump. The membrane filters had been weighed after drying, previously in a laboratory. The used filters were then stored for future drying with subsequent weighing in a laboratory.

An examination was made of the spatial distribution of suspended sediment to establish how representative the sample taken at 60 per cent depth mid-stream was of the complete cross-section of the Samir river. Samples were taken at 20 per cent, 60 per cent and 80 per cent depths on five equally spaced vertical sections across the river.

Observation showed that it would not be possible to predict the total amount of sediment brought down as it depended upon the nature of the snow cover as well as the stream flow; a far greater amount of sediment resulted in the river from melt-water associated with a fine sprinkling of fresh snow over the rocks, than for melt-water from the semi-permanent snow-fields. In addition, even for similar discharges on the rising and falling limbs of the same hydrograph, the suspended sediment load was not the same; the quantity of sediment in the former exceeded that of the latter. The peak value of the suspended sediment preceded that of the peak discharge by some two hours (Figure 3.7.). The variation in hydraulic gradient has a similar relationship with discharge as the peak value precedesthat of the discharge. However, this is unlikely to be the cause of the variation as stream-gauging were performed on both the rising and falling stages and no variation in the stage-discharge relationship was noticed.

Most of the material in suspension is wash load, that is to say it originated from the soil-surface rather than the river channel.. The probable cause of the variation in suspended load for the same discharge on rising and falling hydrograph limbs is the availability of material. The wash load increased when the melt-water flows over the soil-surface rather than from semi-permanent snow-fields. In addition, on the falling limb of a hydrograph where flow velocities are decreasing, some of the larger particles were deposited temporarily on the bed of the river until the next rising hydrograph limb picks up the abundant material and carries it downstream.

The results from the spatial distribution of suspended sediment confirm the assumption that a single mid-stream measurement at 60% depth below the surface is a fair approximation to the average silt discharge across the whole section; the silt measurement at 60% centre depth was 0.0137 gm/l while the average of the fifteen measurements across the river section was 0.0139 gm/l. It is probable that attention should be paid to sample size rather than number of samples.

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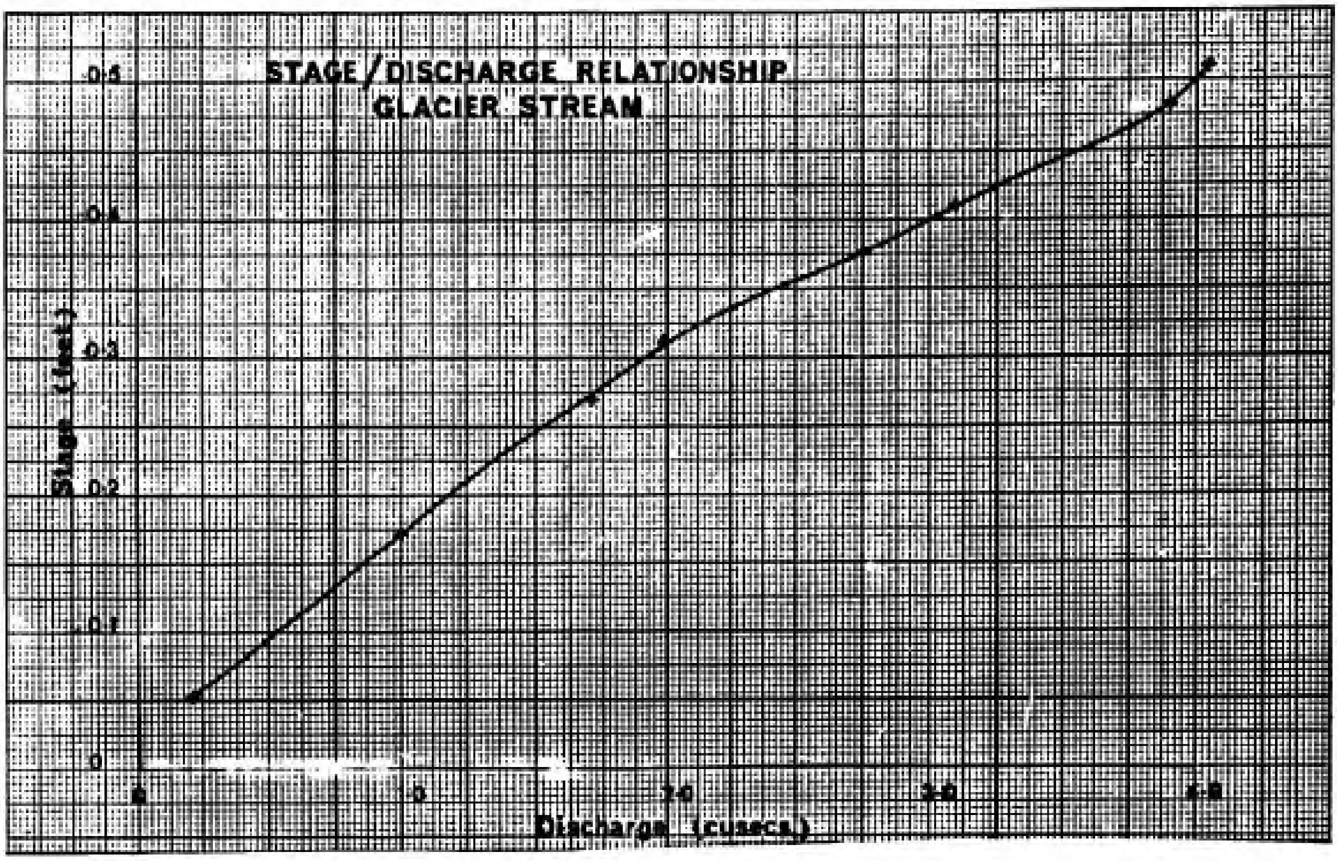

Fig.3.1. Stage/Discharge relationship curve for stream issuing from Mir Samir West Glacier, July/August 1965.

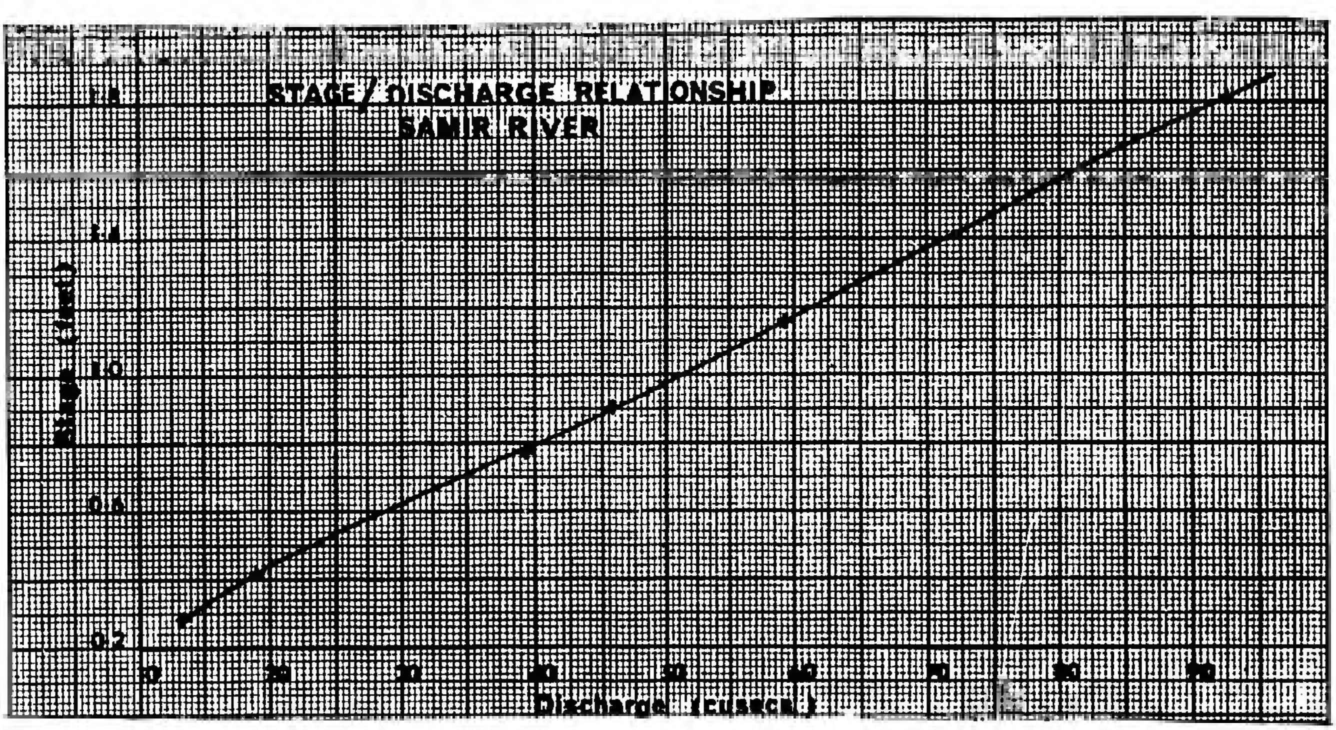

Fig.3.2. Stage/Discharge relationship curve for the Samir River, July/August 1965.

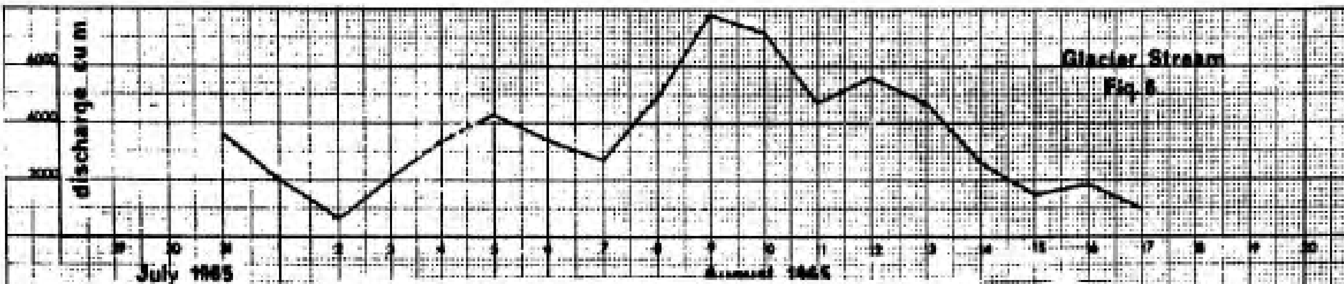

Fig.3.3. Daily variations in discharge from Mir Samir West Glacier in July and August 1965.

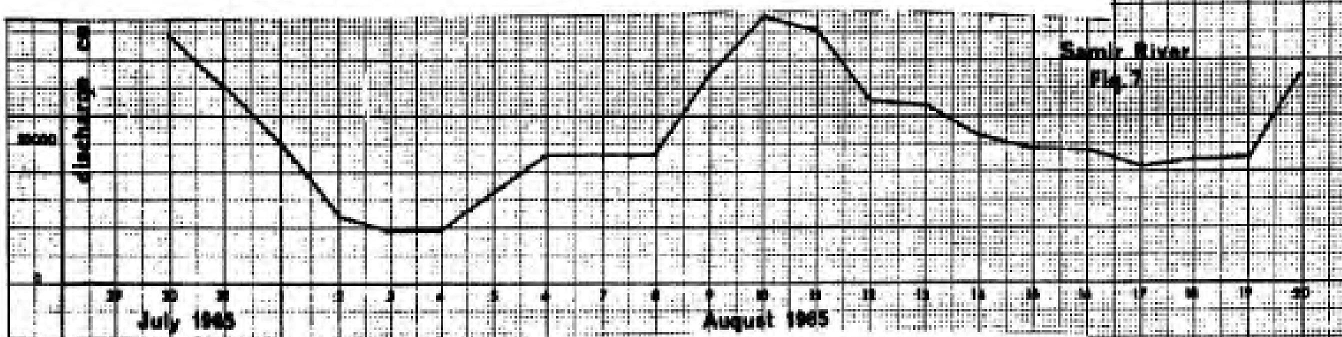

Fig.3.4. Daily variations in flow in the Samir River during July and August 1965.

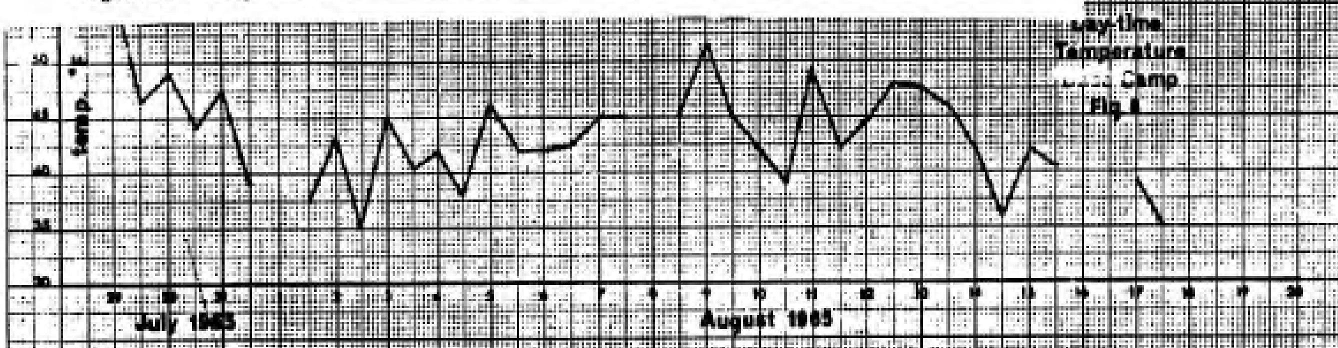

Fig.3.5. Variations in 12-hourly mean temperatures at Base Camp during July and August 1965.

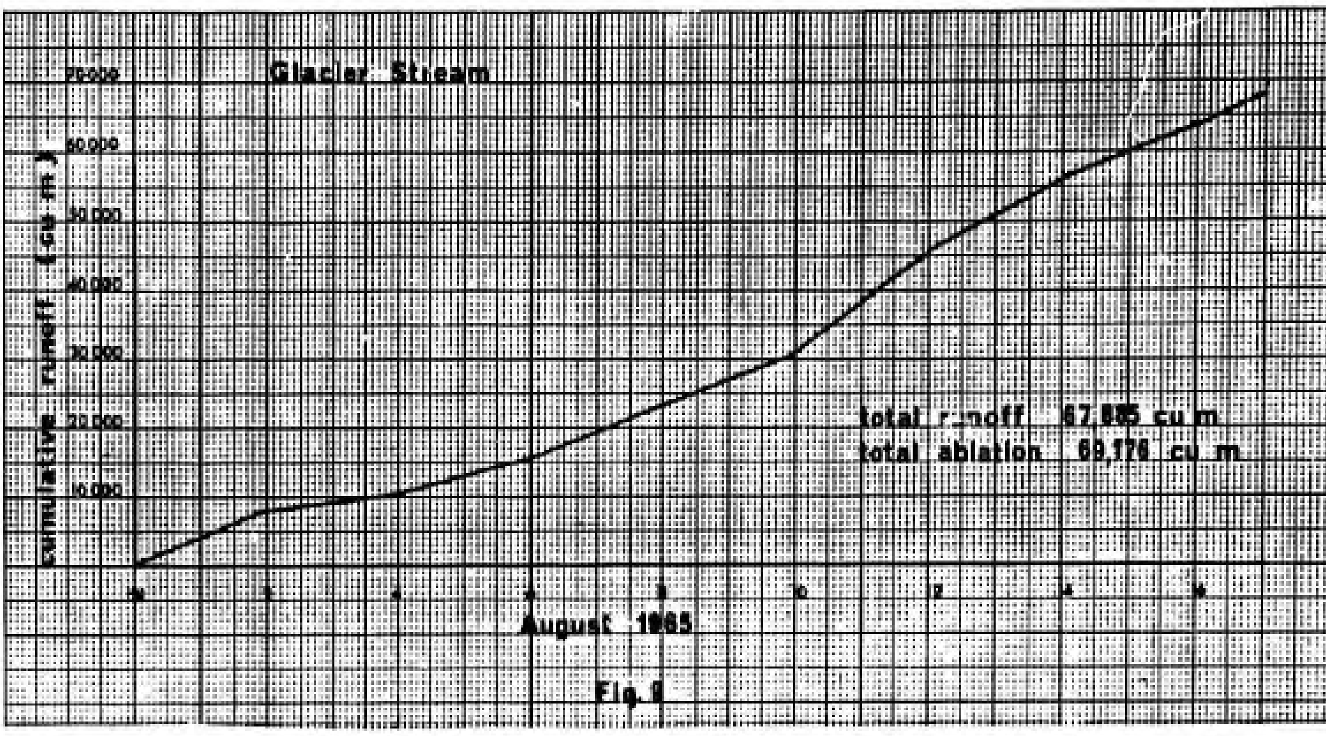

Fig.3.6. Culmulative discharge from Mir Samir West Glacier during August 1965.

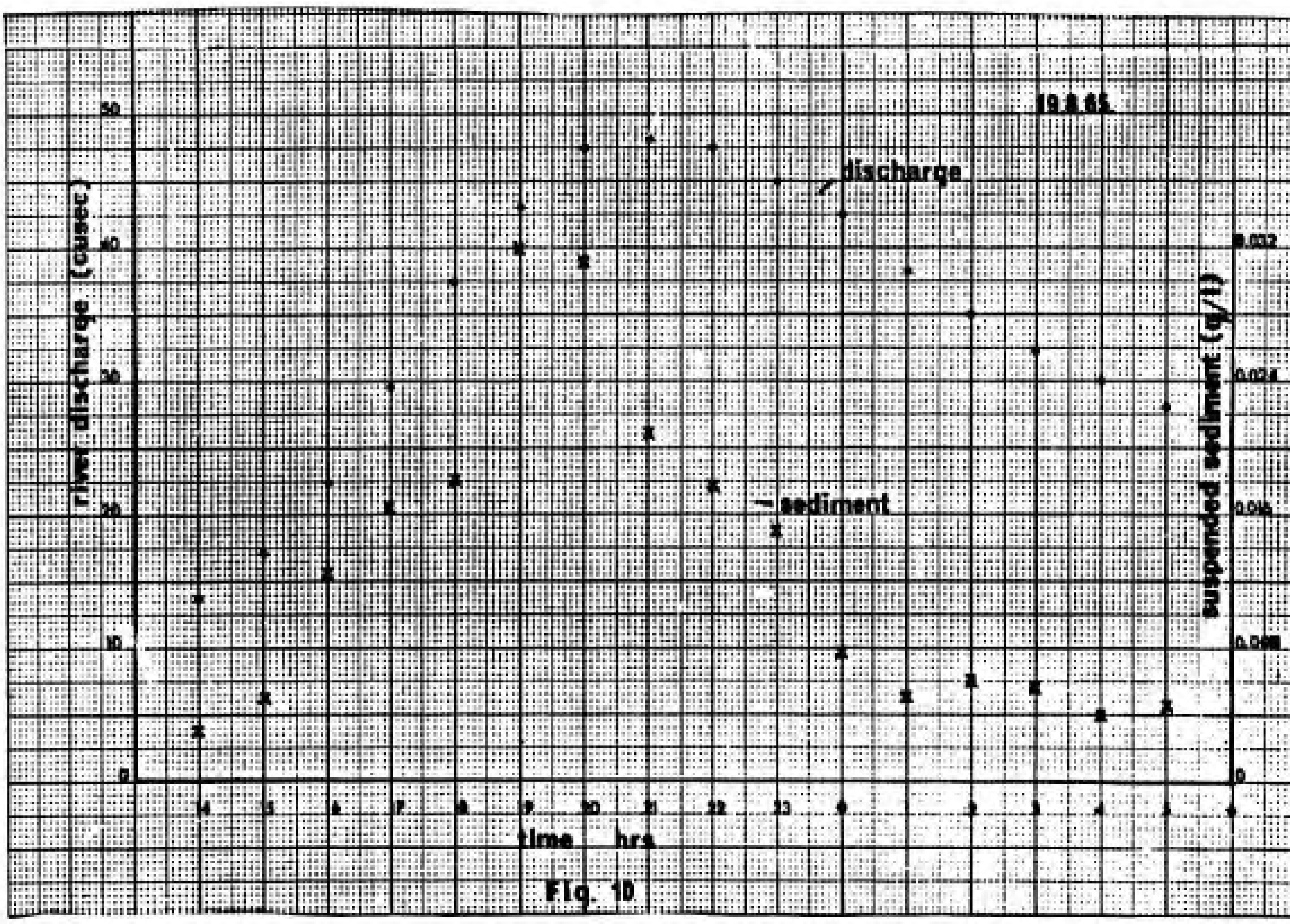

Fig.3.7. Relationship between Discharge and Sediment Transport in the Samir River.

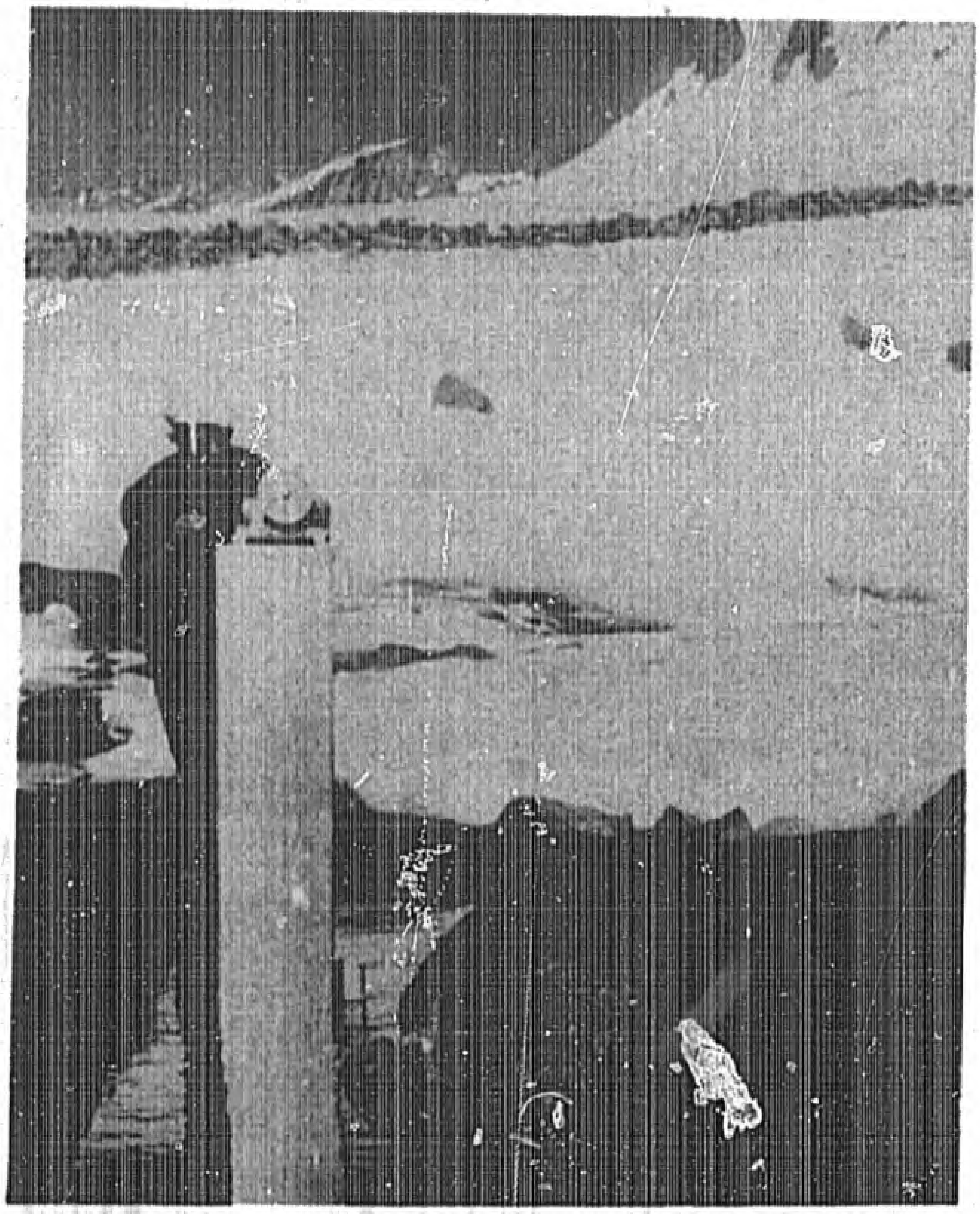

Fig.3.8. Flow gauging station near snout of Mir Samir West Glacier.

GEOMORPHOLOGY REPORT I

Geomorphology in the Samir Valley

by H. Lister and M.J. Earle

Summary

A morphological description is given of a typical area in the Hindu Kush range with some consideration of weathering processes and interpretation of glaciation limits. An excellent general account of the geomorphology of Afghanistan is written by HUMLUM (1959). The account presented here details a high region in the north east.

The region comprises approximately 50 km^2 (20 mls^2) in the highest part of the Hindu Kush, on the northern border of Badakshan with Nuristan. Turretted Alpine peaks rise steeply above 5,000m (16,500 ft.) from knife-like ridges up to 3 km. long. Whilst some of the ridges are straight and saw toothed others encircle corrie basins and hanging valleys which fall sharply into the deeply entrenched tributary valleys of the Panjshir River. (Fig. 4.1.). This main river of the region rised further north in the Hindu Kush, flows south to the Kabul plains finally to join the Indus. Though possibly consequent in origin this river is now superimposed, cutting through many folded structures and across varying angles of dip.

The fold mountains lie from E.N.E. to W.S.W. The highly metamorphosed rock varies from Mica schist to very coarse grained gneisses with large quartz and felspar crystals amid a black network of small ferro-megnesian silicates. The mica schist has weathered by exfoliation into sub-rounded slabs and boulders whilst the gneisses give a dark iron colour upon weathering. Marked joint and fracture planes have weathered into deep clefts and large angular blocks have fallen away to produce steep scree. Frost shattering is the dominant process in the reduction of cliffs and scree blocks, though extensive solutioning and chemical weathering details the blocks, rounding them a little, and rotting the felspars, so producing a large number of elementary soil particles. (Fig. 4.2.). Those rock surfaces which are not washed frequently by summer snow melt are either smooth and black with desert varnish generally precluding lichen growth, or pock-marked and sandy after recent massive weathering and exfoliation.

Intermittent precipitation throughout the year, and extensive snow melt during the summer, washes out most of the weathered material from the steeper slopes. Soil creep fills the gaps between frost shattered blocks and at any slight reduction in the generally steep gradients, soil patches accumulate. Here, and where lines of fine silt have been left by the melting snow, are found flushes of short, coarse sedge dotted with primula and buttercups. The plants growing on the edge of soil patches further from meltwater streams show adaptation to drought. Long Legumes and shiny surfaced succulents such as Sedum Crassipes are common. There is little stability; frequent thunderous rock falls, avalanches down steep snow slopes, diurnal fooding of the snow melt streams and persistent solifluction, rapidly transport much of the weathered material to lower altitudes.

The approximately E. to W. grain of the country rock provides a series of knick points above which ponded streams, depositing their load of fine material, have produced small flats up to 1 km. square. The two highest meadows (c. 4200m, 14,000 ft.) in the Samir Darra were so formed. These are now covered by sedge grass and broken by meandering, meltwater streams. In the early morning or during periods of overcast conditions with temperatures near to freezing point, stream discharge is low and deep silt pools are revealed.

Below the hanging valleys are huge debris fans which in two places extend across the floor of the Samir Darra to meet the scree on the opposite valley wall. Dams have thus been formed across the valley through which the Samir disappears and above which small, flat, silt meadows have been formed. The two lowest "meadows" (c. 3900m 13000 ft.) of the Samir Darra are of this type (see map Fig. 1.1.). Since the control in their formation is not structural they are more narrow than the higher "meadows" but the very slight gradient gives rise to river meanders and cut off lakes. The "meadows", like green beads along the black and brown valley, alternate with rock-filled gorges and are gradually being encroached upon by the coarse scree of the valley walls. All the fine material is being washed out from the debris fans. Streams are frequently only detectable by sound from beneath the broad, steep, block-filled chutes. Since the meadows have not been completely filled in by the coarse scree from massive weathering it seems that silt deposition and soil creep are able to keep pace with the encroachment of these coarse blocks. Transport simply by gravity and transport by fluvial action would seem therefore to be approximately equal in this region for any localised base level.

Frost hummocks (thufur) are particularly common near streams flowing through the "meadows" (Fig. 4.3.). About 80 cm. diameter, these mounds sometimes coalesce into sinuous ridges. A trench dug into some of these revealed a blackened soil layer of approximately 10 cm. merging rapidly with the light brown, fine silt. At a depth of 50 cm. an 8 cm. frozen, horizontal layer marked the top of the water table. Temperature increased from the frozen layer towards the surface reaching $+4^{o}$C at 10 cm. depth. Grass minimum temperatures in July varied little from -5^{o}C. Diurnal freezing was thus very limited in depth and the frost hummocks would seem to be the result of a deeper freezing in winter. Such prolonged freeze- thaw action would require greater time for production of the hummocks.

The hanging valleys perched above the tributary valleys of the Panjshir are short and steep with one or more corries at their head. (Fig. 4.4.). The steep rock walls of the corries may be breached in a high col connecting with the adjacent valley. Where they face north, the corrie walls and flanks of ridges retain much of their snow cover above an ice layer which adheres to the rock. Hence they are really small, perched glaciers which in the past extended over the rock debris that floors the corries. This debris, mainly large blocks resulting from massive weathering, forms a slight hollow often occupied by a lake. The coarse detritus also extends over the corrie lip giving rise to a steep rock slope down to a second, lower, rock-floored corrie.

The hanging valleys which do not face north have little snow by midsummer and dry out across the rock surface beneath which flow small, buried, meltwater streams. In these valleys three or sometimes four successive rock strewn areas of slight gradient (feldsenmeer) connected by steep stone chutes indicate the successive stages of deglaciation.

Depositional evidence of glaciation has been greatly modified by the meltwater channels flowing from snow patch glaciers on north-facing slopes. In few places a cliff too steep to retain snow, has protected part of the floor of the hanging valley and preserved a terrace of glacial debris, encroached upon at its periphery by a small meltwater stream.

The regional snowline is above the highest peaks but on slopes facing north is at 4,900m. (16,000 ft.) but small snow-patch glaciers supplemented by avalanche snow from above extent to 4,930 m. (16,170 ft.). Two main glaciers, c. 1 km^2 and $\frac{1}{2}$ km^2 area, are on the north facing flanks of Mir Samir (5,809 m. 19,060 ft.). Both have high terminal moraines separated almost entirely from the glaciers by meltwater streams. At 4,800m (15,700 ft.) the 20 m. (65 ft.) moraine borders a boulder strewn basin with meltwater lake and is up to 100 metres, (330 ft.) from the glacier snout. (Figs. 4.5. and 4.6.). For observations on glacier mass balance and on interpretation of lichens for glacier recession see GLACIOLOGY I.

Lakes and corrie floors are found below the highest moraine with a common height of approximately 4,600 m. (15,100 ft.). Here, lines of coarse sub-angular blocks remain where the finer glacial debris has been washed out. Many of the rounded ridges and blocks above Upper Newby's lake exhibit marked roche moutonnee form and some are gauged and scratched with striations running almost E. to W.

A third and lower stage of glaciation is indicated by large lateral moraines along the Samir Darra at approx. 4,100m. (13,500 ft.). It is not easy to separate individual remains of glacial evidence from soil creep and the extension scree of the valley walls. A marked change can however be observed in the valley walls a little above 3960 m. (13,000 ft.). Below this height the valley becomes V-shaped rather than U-shaped. Above this height rock debris is ridged parallel to the valley whereas below, it is contiguous with the steep scree that produced it.

The Samir river, over waterfalls, bars and scree, drops in 17 km from 5000 to 2750 m (16,400 to 9000 ft.). where it joins the Panjshir. A little below this confluence where the Panjshir enters some of the intermittent basins, two (in one case 3) distinct river terraces indicate possible correlation with the halt stages interpreted near the head of the Samir valley. Grötzbach (1963) near Salang, about 50 km. to the north, found moraines down to 2300 m (7,500 ft.). but in the rapidly eroding Panjshir, traces of any such advanced position of the ice have been removed.

Erosion surfaces can only be guessed at without much further work in the field with the detailed map now being produced with the aid of the U.N. at the Afghanistan Cartographic Office in Kabul. The map in figure 1 is based upon an advance copy of one sheet of this 1:50,000 map, by kind permission of the Survey Director. The continuation of the west ridge from Mir Samir is topped by a more gentle slope, almost unique in the country rock of the area. This is a single facet of an old erosion surface at nearly 5000 m (16,4000 ft.) which agrees with those found by Grötzbach (1964) 50 km to the north in the upper Imun valleys.

Similar but lower facets of erosion surfaces were seen 100 km (60 mi) to the west on the route to Bamian. These remnant surfaces are bounded by very steep slopes that rise from very gently tops of spurs, a few 100 m. above the present valley floors. Uplift and a not very uniform process or erosion is indicated.

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GEOMORPHOLOGY REPORT II

Geomorphology in West Pakistan

by M.J. Earle and J.H. Parry

Summary

The Attock district and the Kaghan Valley in the Western Himalayas are briefly described and the Salt Range to the South outlined in terms of morphology and genesis.

The paper described very generally the two areas of West Pakistan visited to collect palaeomagnetic specimens.

Two distinct areas were visited in the syntaxial bend of the Western Himalayas. Specimens were collected from the Attock district where Pre-Cambrian and Palaeozoic rocks outcrop in the Indus valley, amidst the Quaternary spreads of detritus, gravel and clay which form the Peshawar Plains. These plains, monotonous and desiccated away from the valleys, approx. 1100 feet above sea-level, are covered by scanty scrub.

Traversing the plains is the vast Indus River which assumes dramatic qualities as it flows through the gorge at Attock. Pre-Cambrian outcrops - Attock slates - occur in the gorge and to the north are Siluro-Devonian sediments, especially shales and sandstones, together with igneous rocks.

In the Monsoon, flow is high and floods rapid. Similarly there is danger in spring when the Himalayan snows melt. Disastrous inundations have been recorded throughout history, the most notable perhaps being that in 1841 which swept away a whole Sikh army.

The Kaghan valley further to the north was next visited. From the plains, the Outer Himalayas are first encountered. They form a system of low foot-hills with an average height of 3000 to 4000 feet, supporting poor quality grasses, occasional trees and scrub. In the river valleys, the hill-sides are often terraced, and with controlled irrigation, rice and perhaps another cereal crop are grown.

Next are the lesser Himalayas, including the Kaghan valley, which seldom rise much above 12000 to 15000 feet. Pine-woods cover the slopes and in the Kaghan valley, forestry plays an important role in the economy. In this eara it is particularly evident that the older rocks have been thrust southwards over the younger formations. Of the latter, the Murree beds of Miocene Age are most common along the thrust. These beds comprise dark-coloured sandstones and purple splintery shales. The angle and effect of the thrust recall the thrust planes of the Scottish Highlands. Dolerites and other basic igneous rocks are also represented.

The rivers in this area are in a youthful stage. Rapid in flow, they accomplish much erosion. In the Middle Himalayas they generally have gorge sections, as does the Kaghan valley, with numerous waterfalls and rapids. (Figure 4.7.)

Slope development is proceeding by fluvial erosion and solifluction. Landslips are common - the Kaghan road to Gilgit, closed in winter, is constantly being cleared in summer - and slumping is common. Indeed quite often it is difficult to tell whether a sizeable face of rock is a true exposure or a fallen boulder. This complication, together with the highly contorted nature of many of the beds, considerably limited the field for specimens.

A second project involved work in the Salt Range much further south. To reach it, the Potwar Plateau was traversed. This is an elevated plain composed of Tertiary sediments laid down in the Potwar Geosyncline. On top of the Tertiary sediments are recent accumulations of loess, glacial boulders and fluvial deposits. Sections show the loess, derived from the Plains and dried up river basins to the south, forming a thick cover. In places gully erosion in sudden downpours has carved a badlands landscape. Elsewhere is a carpet of alluvium from the rivers traversing the plateaus. Large boulders found on the surface are possible glacial erratics brought down from the Himalayas.

Where rivers cross the plateau they flow through wide valleys that are obstacles to communications. Smaller but ephemeral streams abound.

Between the Potwar Plateau and the Punjab is the Salt Range. Sinuous in outline, it is a continuous range of low flat-topped mountains rising abruptly out of the flat Punjab and extending from longitude 71°E to 74°E with an approximate east-west strike. It presents a scarp-face to the Punjab, the uppermost scarp along its whole length being a prominent cliff of nummulitic (Mid-Eocene) limestone. With its precipices and defiles most of the geological systems are displayed, although they are much displaced by a number of transverse dip faults.

The orthoclinal outline, that is the steep southern scarp and the long gentle northern slope, suggests that these mountains are the result of a monoclinal uplift combined with a lateral thrust from the north, which has depressed the southern part of the monocline under the Punjab Plain, while the upper part has travelled some distance over it along a gentle plane of thrust.

Above the scarps and cliffs of the southern edge therefore is a nearly level plateau top which merges northwards into the Potwar Plateau. As a result, the older Palaeozoic rocks are exposed in the escarpments, and the younger Tertiaries lie behind. The southern edge is crenulated by a number of deep gullies and ravines. In these is revealed the stratigraphy of the Salt Range, so observations were focussed in the Khewra gorge in the east, and the Nammal gorge in the west.

These gorges are typical desert gorges with flat floors and steep sides carved into desert sandstones. The floors of both gorges are covered in assorted rock debris, the result of weathering induced by temperature changes.

Transport of this material is slow since the gorges are occupied but rarely by any volume of water. The lower sections of the gorges had considerable numbers of boulders and where the ravines opened out on to the plains, heaps of talus had accumulated. They were not yet by any means pediment formations. Aridity permitted little vegetation to protect the rocks from weathering.

The Khewra and Nammal Gorges each had a small stream, hardly more than a trickle, but in the lower reaches of Khewra gorge this was braided. The groundwater of the Salt Range is generally saline owing to the presence of rock-salt which gives the range its name. The stream at Khewra was saline and its banks were covered in salt. At Nammal the salinity was absent, but in its lower reaches the stream was sulphurous being supplied by a sulphur spring near the mouth of the valley. Thermal sulphurous springs are numerous on the outcrops of Nummulitic limestone. The streams in both gorges appeared to be spring-fed, and in all probability spring-sapping on a small scale was effective at the valley heads. Where the sulphur spring appeared, slimy and pungent deposits of sulphur had formed.

In the wet season (summer) infrequently heavy rainstorms associated with the monsoon may occur. At such a time, the gorges of the Salt Range are transformed into raging torrents with very little warning. They engulf all before them and are extremely effective agents of transportation, flushing out all the accumulated rubble on the gorge floor. In 1948 a flashflood in the Khewra gorge destroyed most of the settlement of Khewra at the scarpfoot. In the main, however, they are cauldrons of heat in summer with high radiation from the gorge walls and consequent exfoliation.

On top of the range there are wide deposits of loess as in Potwar to the North. Rough grasses form a scanty vegetation cover, and capillary tubes are in evidence in the loess. Also like Potwar, occasional badland tracts occur but not on so wide a scale.

Rocks of most ages are present in the Salt Range including the vast Eocene salt deposits, but of particular interest for continental drift is the Talchir Boulder Bed of Upper Carboniferous age. The boulder bed is generally regarded as glacial in origin and has a wide distribution in widely separated localities of the Indian sub-continent. It may be found not only in the Salt Range but also in Hazara, Simla, Rajputana, Orissa and elsewhere, wherever lower Gondwanaland rocks outcrop. A glacial period at the commencement of the Upper Carboniferous has been inferred, and this lends support to the hypothesis that the landmass of India has drifted north from south polar latitudes.

In order to try and test this hypothesis, palaeomagnetic specimens were taken from the sand stones adjacent to the Talchir Boulder Bed. Further detail is included in the geophysics report, but here are impressions gained merely from geological examination.

The evidence ammassed by geologists in the past for a glacial origin may be summarised: There exist characteristic marks of glacial action in all the outcrops. Beds of compacted "boulder-clay" or glacial drift rest on an undersurface sharply defined by being planed and striated by glaciers. The constituent materials are heterogeneous in type and grade. Origins of component boulders are distant and varied, and there is no assortment or stratification visible. Writers claim that in the Salt Range, boulders recognisable in the bed include rhyolites, felsites and granites, many of which are striated and polished. Intermixed are smaller pebbles from various other crystalline rocks which are embedded in a fine, dense matrix of clay. Some constituents are supposed to show facetting. (Figure 4.8.)

From my examination, certainly the boulders vary in size, shape and type. The photograph shows what may be termed boulders on the one hand, and pebbles on the other. They are also embedded in a fine and not especially resistant matrix. Large pieces of deep, pink granite, containing much orthoclase felspar were present (similar to Shap granite), and finer granitic materials, probably rhyolites, were visible. Obsidian was more rare.

The shape of the pebbles is a reliable guide to conditions of formation. If it were a true conglomerate, the constituents would be rounded. However, if it were a breccia, likely to be formed in arid conditions where occasional torrents prevailed, the pebbles might be angular. In the exposure of the bed visited, it could not be asserted that angular or rounded pebbles were dominant. Instead (evident in the photograph) rounded and sub-angular members are the rule. This indicated glacial origin. Furthermore, the complete lack of grading, again obvious in the photograph, is a further indication of a glacial formation. (Fig. 4.8.)

There, however, agreement with past workers ends. Concrete evidence would be the planation and striation of the bed below. It was impossible to test this assertion. Striations on the pebbles too seemed absent, but distinct polishing certainly existed. One writer's claim that roches moutonnees could be found cannot be substantiated. It is felt that the Talchir Boulder Bed is neither a true conglomerate nor a breccia, and that indications of glacial origin without doubt exist.

In conclusion, it is evident that the Salt Range has had a complex geological history, and that today's landform evolution is no less interesting. There exists much opportunity for further work.

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Fig.4.1. Samir Valley; steeply entrenched valleys with higher empty corries in middle right; sharp ridges with debris fans below on left; Western Hindu Kush behind.

Fig.4.2. Sparse grass over silt-floored basin at 4200m in Samir Valley with rock fall, moraines, Mir Samir West Glacier and Mir Samir behind.

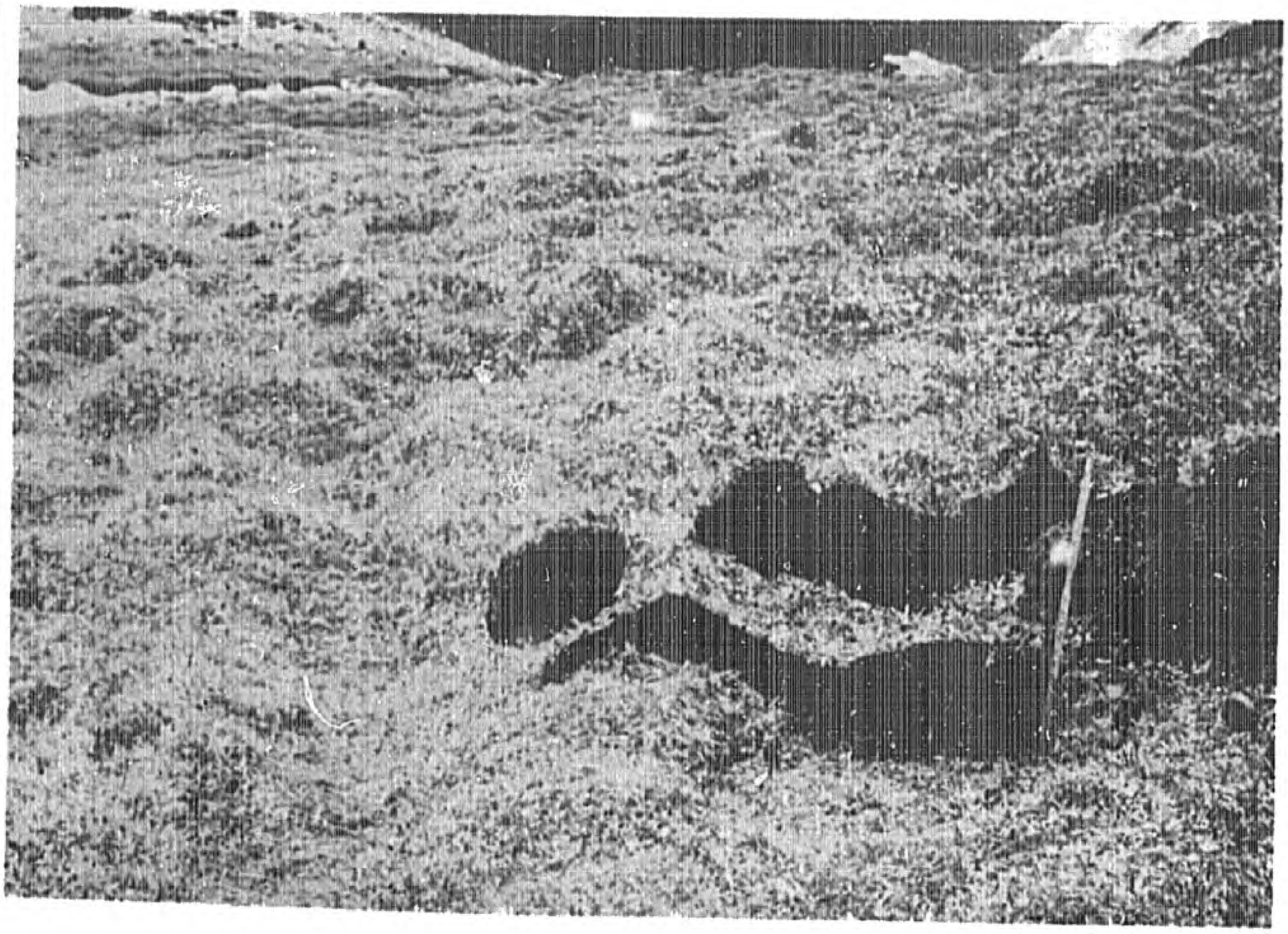

Fig.4.3. Frost hummocks with stream to left and knick-point in background which has caused the silt accumulation, forming the 'meadow' of the basin floor.

Fig.4.4. Hanging valley and corrie below sharp ridges. North facing slopes retains avalanche-fed glacier.

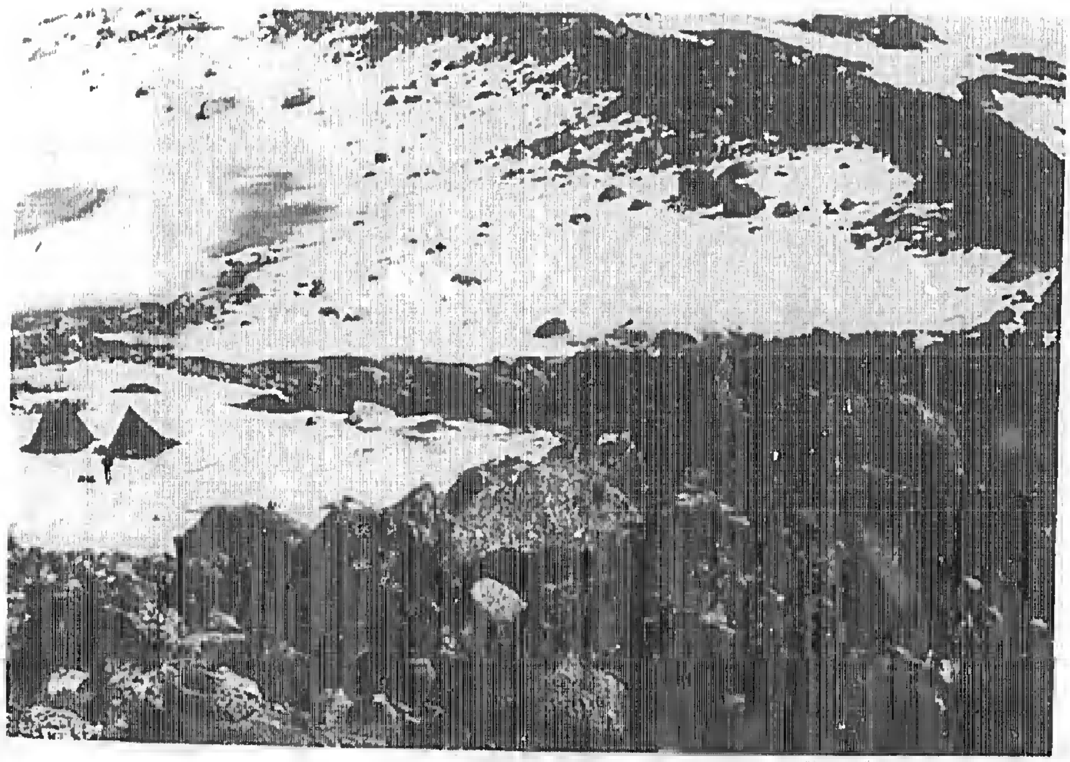

Fig.4.5. High terminal moraine at 4,800m separated from Mir Samir West Glacier to left and background by meltwater lake in boulder-strewn basin across which glacier has advanced and retreated many times.

Fig.4.6. Smoothed ridges with striations; terminal moraine; Mir Samir West Glacier, with bergschrund on right - 4,800m.

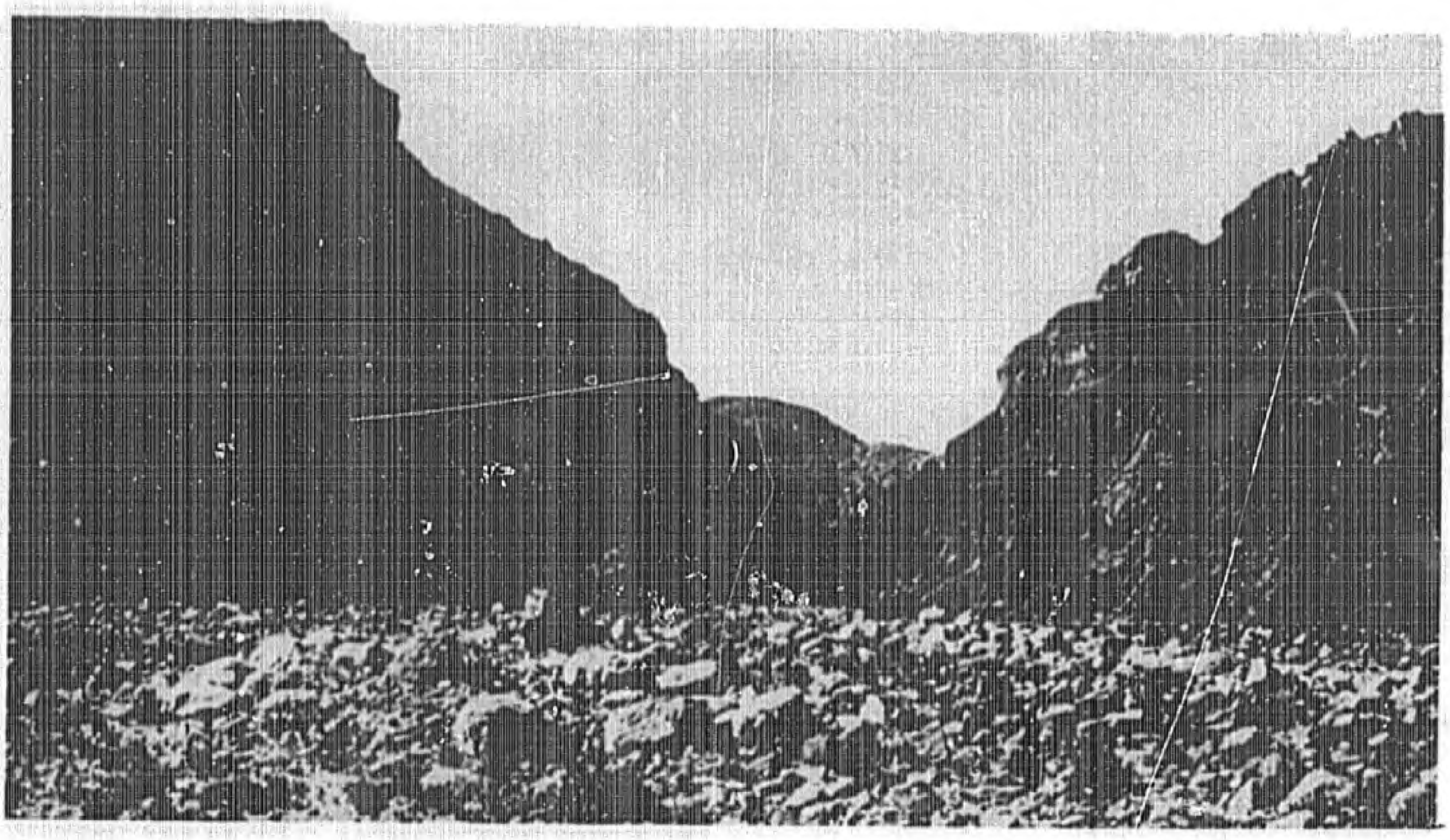

Fig.4.7. <u>Khewra Gorge</u>. The steep sides show rapid weathering of desert sandstones. The rubble over the flat floor will be moved downstream in the next flood.

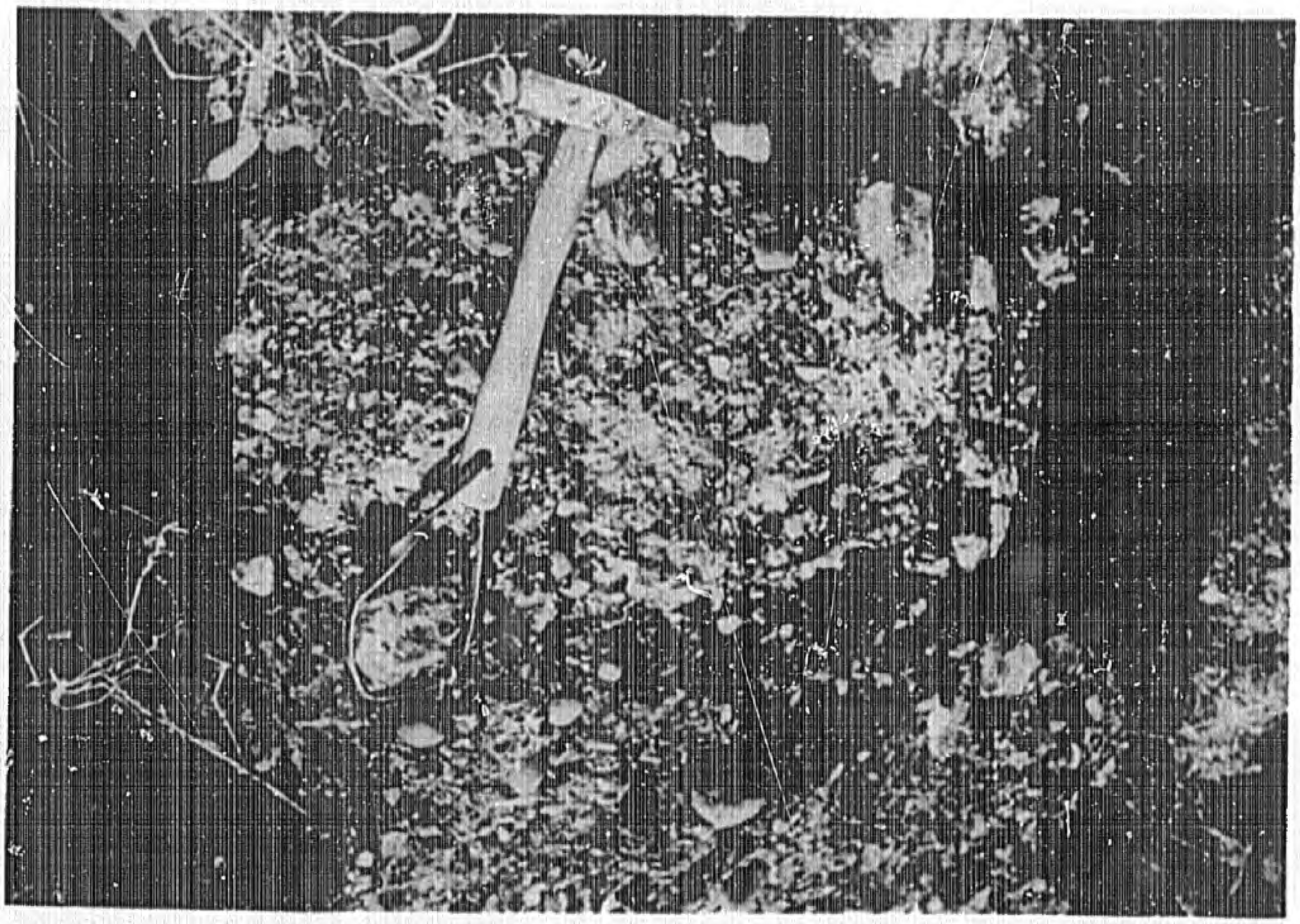

Fig.4.8. <u>Talchir Boulder Bed</u>

Note: 1 the unsorted material;

2 the polished rounded pebbles above the hammer sling;

3 the sub angular pebbles

4 the cavity at bottom right suggesting a not very resistant matrix

5 pink granite inside and to the left of the sling, with obsidian at top right.

LIMNOLOGY REPORT

An Ecological Survey of High-Altitude Lakes in the Samir Valley

by A. James and J. Hubbick

Summary

Physical, chemical and biological studies were carried out on three lakes situated between 3,000m. and 5,000m. in the Samir Valley. All the lakes presented interesting features and their ecology is discussed in relation to the findings from other arctic and alpine lakes. Apart from the ecological interest, the potential yield of fish from projected resevoirs is discussed.

Introduction

Due to a variety of glacial phenomena, there are a vast number of lakes situated at high altitudes in the Alps, Himalayas, Andes etc. Very few ecological studies have been carried out on these lakes, which is unfortunate since they present many interesting ecological features. They show not only the simplified trophic structure of an extreme environment but also examples of the effect of chance introductions on the population dynamics. The productivity data are also useful, for by extrapolation it is possible to assess the potential value of a reservoir scheme for fish culture. This is especially significant in areas where the diet is deficient in protein. Studies were therefore made of the three major lakes in the Samir Valley.

Description of the Lakes

The location of the three lakes studied is shown in Fig.1.1. The morphometry and drainage pattern of each lake is described below.

a) Upper Newby's Lake. This was the largest of the lakes and also the deepest. It was situated as shown in Fig.1.1 at an altitude of 4,650m. in a hollow beside an old lateral moraine. The approximate morphometry is shown in Fig. 5.1. The most prominent feature is a deep trench running east-west which is an ice-gouged channel more than five metres deep. To the south the shore-line is composed of a wide, smooth, rocky shelf partly covered with sand especially at the south-east end. The remainder of the perimeter is boulder-strewn, particularly in the north and west. Drainage into and out of the lake is rather complex. Part of the stream flowing from the glacier snout passes under the lateral moraine and enters the lake underground in the north-east corner. The level of the lake is controlled by the height of the lip at the south end. Excess water overflows there and joins the effluent from Lower Newby's lake. There appeared to be four main types of environment in the lake, namely:

- i) Flat rocks with some sand cover on the southern margin.
- ii) Boulders and smaller rocks on the northern margin.
- iii) Sandy spits projecting out into the lake at a depth of 1-2 m.
- iv) Planktonic.

Samples for biological analysis were taken from all four different habitats.

b) Lower Newby's Lake. This was a somewhat smaller lake occupying a similar ice-gouged trench which in recent times had been occupied by the Samir glacier. It was about 30 m. below Newby's Lake. The East end of the lake is bounded by a large wall of boulders which is part of an old terminal moraine. The sourthern margin of the lake is formed by a steep scree slope, permanently snow covered, which goes up to the Sons of Mir Samir (Pessaran - E - Samir). The remainder of the shore line is more gently sloping and consists of shelving rocks partly soil covered and occasionally strewn with boulders. Water enters the lake in the eastern corner from a stream which drains the southern part of the glacier. This is supplemented for part of the time by melt water from the southern slopes. Water leaves the lake by overflowing in the north-west corner. The lake, as shown in Fig. 5.2. is comparatively shallow over a large area and only in the south-east corner does it exceed two metres in depth. The lake floor and the submerged boulders are all covered with a layer of glacial silt. Four different types of habitat could be distinguished, namely:

i) Silt-covered boulders in the north and east
ii) Sandy gently-shelving shore further west.
iii) Silt-covered bed 2 - 3 metres deep.
iv) Planktonic.

c) Meadow Lake. This is a small lake formed by a cut-off meander of the Samir River. It is situated on a grassy meadow at 2,950 m. at the entrance to the Upper Samir Valley. During periods of high flow the Meadow Lake is contiguous with the river, but in times of low flow it receives only slight lateral drainage and its volume decreases. The approximate morphometry in July 1965 is shown in Fig. 5.3. At the end of August it had decreased to about 2/3 of that area. The eastern margin of the lake was formed by the scree slope of the valley side. The remainder of the lake margin and the majority of the lake bed consisted of mud-covered rock. There were only three main types of habitat in the lake, namely:

i) Mud-covered rock round the western edge and over most of the lake bed.
ii) Submerged boulders on the eastern margin.
iii) Planktonic.

Chemical and Physical Features

Samples of water for chemical analysis were collected at three points in each of the lakes. These were analysed on return to England. As the results of the analyses showed that the water in each of the lakes was thoroughly mixed, the results are presented in Table 5.1. as average concentrations for each lake.

No measurements were made of the concentration of dissolved oxygen as there was no reason to suppose that the water in the lakes was not fully saturated. The saturation value for oxygen in water at the altitudes of the lakes were later computed as given in Table 5.2.

Table 5.1. Water quality of three lakes in the Samir Valley with results from a similar lake in Tibet. (HUTCHINSON 1937).

	Upper Newby's Lake	Lower Newby's Lake	Meadow Lake	Yaye Tso
pH	7.5	7.5	7.2	7.5 - 8.7
Na	4	4	15	12
K	1	1	5	6
Ca	3	3	12	17
Mg	1	1	6	6
SO_4	4	3	18	7
Cl	2	2	6	1
CO_3	2	2	84	122
Phosphorus	0.01	0	0.08	0.04
Nitrogen	0.1	0.01	0.6	Not recorded

All concentrations are in mg/l.

Table 5.2. Saturation values of dissolved oxygen for air saturated water at different altitudes and temperatures. The figures 1,2 and 3 refer to Upper Newby's, Lower Newby's and Meadow Lakes respectively.

	Temperatures					
Altitude	0^oC	5^oC	10^oC	15^oC	20^oC	25^oC
Sea Level	14.6	12.8	11.3	10.2	9.2	8.4
1,000 m.	12.8	11.3	10.0	9.1	8.2	7.4
2,000 m.	11.5	10.0	8.9	7.9	7.1	6.5
2,500 m.	10.7	9.4	8.3	7.5	6.7	6.1
3,000 m.	10.0	8.8	7.7	(3) 7.0	6.3	5.7
3,500 m.	9.5	8.2	7.4	6.6	5.9	5.4
4,000 m.	8.9	(2) 7.7	6.8	6.1	5.5	5.0
4,500 m.	8.3	(1) 7.2	6.4	5.7	5.1	4.7
5,000 m.	7.9	7.0	6.1	5.5	4.9	4.5

All concentrations are in mg/l

The values in Table 5.2 were computed using the equation given in ANON (1965).

$$S^1 = \frac{S \times P - p}{760 - p}$$

where S^1 = saturation value at height h
S = saturation value at sea level
P = barometric pressure at height h
p = vapour pressure of water

The vapour pressure values were obtained from WEAST (1964) and the barometric pressures were calculated from Schassmann's equation -

$$\text{Log } P = \text{Log } 760 - \frac{h}{760 - p}$$

where h = height in metres

as quoted by MORTIMER (1956).

Temperature profiles in the lakes were obtained using a thermistor probe. The results, expressed as means of two sets of readings obtained on different days, are given in Table 5.3.

Table 5.3. Temperature profile in the Samir Lakes.

Temperature in °C

Depth in metres	Upper Newby's Lake	Lower Newby's Lake	Meadow Lake
0	7.2	8.1	15.8
0.5	6.8	7.0	15.1
1.0	3.5	4.0	15.0
1.5	3.5	3.5	-
2.0	3.2	3.5	-
2.5	3.3	3.5	-
3.0	3.3	-	-
3.5	3.5	-	-

It should be stressed that the temperature readings given in Table 5.3. are characteristic only of daytime values in July and August. Even during this brief summer period ice formed on the upper lakes at night.

Biological Surveys

Surveys were made of the animal and plant populations of the lakes. In each lake two metre quadrats were examined in each of the different types of habitat. It was not possible to make a completely quantitative assessment of the communities on account of the rocky nature of the terrain. Instead a standardised netting technique was used for a thirty minute sampling period. This was sufficient to collect the majority of animals in the area. Algal samples were obtained as scrapings from stones or in the water samples, and are also only semi-quantitative. Zooplankton were present in only the Meadow Lake and were collected there by netting while resting on the bed in the sampling areas. The results are therefore reported (Table 5.4) for the benthic sampling areas no results are given for the water samples.

Difficulty was encountered in identifying the preserved material on returning to England, particularly as no keys to Afghan invertebrates are available. Identifications are correct only to the genera.

Discussion

a) Influence of Environmental Factors

The energy budget of the Samir lakes is similar to that of the Tibetan lakes studied by HUTCHINSON (1937). The energy received from solar radiation compares with that of low altitude temperate lakes and would be sufficient to support an eutrophic condition. In spite of the resemblance between the energy budgets of the high altitude and temperate groups of lakes it is probable that the distribution of energy over the annual cycle is different. Also the effect of freezing will be different in the two groups both in terms of the amount of energy used in melting, and also in reducing light penetration into the lake. The latter effect is not as pronounced as would be expected, except where there is a thick snow cover overlaying the ice. The extent of the inhibition is determined by a combination of three factors:

i) The extreme clarity of the water in high mountain lakes giving Secchi disc reading of up to 20 metres (RODHE 1966)

ii) Superoptimal light intensities. For pelagic photosynthesis optimal light intensities are generally only 30 - 70% of the incident radiation.

Table 5.4. Benthic populations of the Samir Lakes (The numbers 1, 2 & 3 for each lake refer to the sampling sites as marked on the appropriate Figs.).

Organism		Upper Newby			Lower Newby			Meadow		
Group	Genus[1]	1	2	3	1	2	3	1	2	3
Algae	Oscillatoria	P	A	A	A	A	A	P	A	A
	Pleurocapsca	P	P	A	A	P	A	P	A	A
	Cymbella	A	A	A	A	A	A	P	P	P
Angiosperma	Starwort	A	A	A	A	A	A	P	A	A
	Sedge	A	A	A	A	A	A	P	A	A
Protozoa	Colpidium	A	A	A	A	A	A	P	P	P
	Colpoda	P	A	A	A	A	A	P	P	P
Rotifera	Hydatina	A	A	A	A	A	A	P	P	A
Nematoda	Rhabditis	A	A	A	A	A	A	A	P	A
Crustacea	Diaptomus	1	0	0	0	0	0	8	0	1
	Eucypris	0	0	0	0	0	0	35	5	42
Plecoptera	Capnia[2]	2	5	1	0	0	0	5	12	0
	Perla	3	6	0	0	0	0	6	8	1
Ephemeroptera	Ecdyonurus	6	8	1	0	0	0	4	12	0
	Ephemera	3	7	1	0	0	0	10	10	8
Tricoptera	Limnephilidae[3]	3	3	1	0	0	0	12	2	10
	Phryganea	1	2	0	0	0	0	10	10	8
Coleoptera	Hydroporus	0	0	0	0	0	0	0	2	0
Diptera	Orthocladimae	12	20	0	1	3	0	8	18	2
	Simulium	0	1	0	0	0	0	2	1	0
Neuroptera	Sialis	0	0	0	0	0	0	0	1	0

Notes

1. In some cases it was not possible to identify the material to generic level.
2. The absence of external wing pads prevents accurate family determination.
3. Noted by NEWBY (1958).
4. Organism numbers refer to the total collected per 2 m quadrat. Plants are recorded as present or absent.

This gives in the ice-free summer period a zone of inhibition in the top layers of the lake (FINDENEGG 1962, HOBBIE 1962). It has been pointed out by RODHE (1966) that superoptimal intensities of visible energy alone would not suffice to cause this zone of inhibition and it seems probable that Ultra-Violet light plays a major role. The high intensities of U.V. light are thought to be responsible for encouraging the dominance of the strongly pigmented forms amongst the Crustacea (LOFFLER 1962).

iii) The adaptation of Algae to low light intensities. It has been shown by HOBBIE (1962) that in arctic Alaskan lakes which have a similar period of ice cover to the Samir lakes, the algae are adapted to low light intensities to the point where productivity is reduced when the ice melts (see Fig. 5.4.).

It may be concluded that whatever factor is chiefly responsible for the ultraoligotrophic condition of the Upper Samir lakes it is not the energy source. In the case of the Meadow lake the energy received from solar radiation is supplemented to some extent by empneuston (wind-blown organic matter) and the lake may be classified as partly allotrophic.

Low temperatures in the Upper Samir lakes occur even during the short summer period and obviously exert a depressing effect on the metabolic activity of the lake communities. These two lakes are capable of supporting only psychrophilic algae. The Meadow lake has much higher summer temperatures which are comparable with the epilimnion temperatures of a temperate lake. This may explain in part the greater diversity of organisms, especially algae, found in this lake. It has been observed that in most high altitude lakes thermal stratification, if any, is slight (RODHE 1966) and this was found to apply to the rather shallow Samir lakes. During the summer, due to high light intensities, a day-time stratification occurred as indicated in Table 5.2., but this did not survive the low night temperatures. Because of this lack of thermal stratification, water in the lakes was well mixed and the lakes could be classified as cold polymictic (Upper and Lower Newby's) and warm polymictic (Meadow).

From the results of the chemical analyses it is possible to classify the Upper Samir lakes as ultraoligotrophic. They have much lower concentrations of dissolved salts than even the most barren of the Tibetan lakes studied by HUTCHINSON (Yaye Tso). It is probable that this lack of inorganic nutrients is one of the main factors causing the low productivity. The rock over which the glacial streams flow is mainly mica schist which is comparatively rich in soluble minerals and as STROM (1935) pointed out, moraines are an important source of electrolytes in mountain lakes. In the case of the Upper Samir lakes the low level of these nutrients is due to the short distance travelled by the inflowing streams. Further down the valley both the Samir River and the Meadow Lake are comparatively rich in inorganic salts and this lake may be classed as mesotrophic.

In all of the lakes the pH values were near neutrality and the saturation values of dissolved oxygen as computed in Table 5.2. were unlikely to be limiting. The oxygen concentration can easily become limiting in high altitude lakes, especially where there is thermal stratification. HUTCHINSON considered that the fauna of the Yaye Tso was limited for this reason.

As well as nutrients glacial streams also tend to contain a large amount of silt. Values of 0.0139 g/l were recorded for the Samir River. When the flow in the river is checked by decreasing gradient such as on the Base Camp meadow or in Lower Newby's Lake, much of the sediment is deposited. The influence of this material in blanketing the bed of Lower Newby's Lake was to render the environment unsuitable for benthic organisms. As these constitute the majority of forms found in the upper valley, this lake was virtually sterile. In Upper Newby's Lake the influent was mainly by seepage so that the amount of silt was much reduced. The amount of silt present in the Meadow Lake was considerable, but the largest population here was zooplankton which are not affected to the same extent.

Another factor of extreme importance in determining the lake communities is difficulties of colonisation. These are dependent on two things, the chance of animals and plants being introduced and the age of the lakes. The age of the Samir Lakes has been estimated at between 10,000 and 20,000 years. (This estimate is based on lichen dating of the glaciological phenomena and is explained in section I of this report). The chances of introduction of animals which have an aerial stage in their life history are obviously much greater than those of purely aquatic forms and this is reflected in the species composition of the communities. The purely aquatic organisms rely on passive dispersal by wind or larger animals. In this context LOFFLER (1962) has remarked upon the differences which exist between lakes in different mountain ranges. He contrasted the Andes, as a climatic highway along which a bird migration exists, with the African mountains as islands of cool climate in a tropical belt where waterfowl are scarce and migration is limited. Although the Hindu Kush, Karakoram and Himalas form a large climatic block, waterfowl are rare and colonisation is extremely slow. Domestic animals may have helped to introduce organisms into the Meadow Lake, but the grazing zone does not extend up to the Upper Lakes and their fauna and flora are accordingly more restricted.

b) <u>Biotic Considerations</u>

The most outstanding biological feature was the lack of life in Lower Newby's Lake. This was especially difficult to understand in view of the similarities with Upper Newby's Lake. Whatever organisms have colonised the Upper Lake have had an equal opportunity for colonising the Lower. There appeared to be two reasons for the barenness of this lake:

i) The direct entry of a glacial stream caused the deposition of large quantities of silt on the bed of the lake. This type of surface is not suitable for benthic organisms and as there were no plantonic forms, this severely restricted colonisation.

ii) It is not possible to estimate the thickness of ice cover during the winter, but this may well reach two metres. Only a very small area of the lake is over two metres deep so that this would decimate the lake community every winter. As recolonisation is slow, this would tend to prevent any community developing.

The other two lakes supported communities which seemed to be more in the line with their energy budgets and locations. A generalised food web for the two lakes is presented in Fig. 5.5. Although this refers to both lakes, some of the groups are missing in Upper Newby's Lake and the food web is even more simplified. The groups missing from this lake - Rotifera, Nematoda, Protozoa and Crustacea (1 Daphnid found) are all planktonic forms. The presence or absence of zoo-planton is the major biological difference between these two lakes. In the ultraoligotrophic condition of Upper Newby's Lake, with only benthic organisms, the ultimate predators, Tricopterans, are efficient and a balanced community is achieved. Where zooplankton occur it is doubtful whether Tricopteran predation is effective. Tests carried out in small tubes showed that Tricoptera would eat Crustacea, Plecoptera, Ephemeroptera and Diptera, but in the lake this predation would be limited by the slow speed and benthic nature of the Caddis Larvae. This was confirmed in pools left behind by the retreating Meadow Lake where Tricoptera quickly reduced the Crustacean oppulations in a confined area. LELLAK (1963) observed that in ponds where fish had been removed there was no longer an effective predator for zooplankton and so they increased tremendously, especially the Crustaceans. Another feature which must assist in the Crustacean dominance of the Meadow Lake is their resistance to the seasonal dessication. During July and August 1965 both the area and depth of the Meadow Lake were considerably reduced in more extreme summers the lake may disappear. Under these conditions the lake will be dominated by organisms which are resistant to desiccation. It has been pointed out by HARTLAND - ROWE (1966) and RZOSKA (1964) that Crustacea are amongst the most resistant of aquatic organisms to drying.

A noteworthy feature of all the Samir Lakes is the scarcity of Algae both in numbers and variety of species. This is understandable in the case of the upper lakes because of the problems of colonisation and the low level of nutrient salts, but for the Meadow Lake the explanation must be more complex and is possibly due to a combination of the following factors:

i) The unstable nature of the bed of the lake which is not suitable except on the east shore line, for the growth of benthic algae.

ii) Seasonal variations in the area of the lake which expose many planktonic algae to desiccation. This, together with periodic flushings due to high stream flows, will restrict the number of planktonic algae.

iii) Problems of colonisation.
iv) Severe predation due to the large populations of zooplankton.

In the Meadow Lake, due to the paucity of Algae, the main food chain must be Detritus-Protozoa (and/or Rotifera and Nematoda) - Crustacea - Tricopera, and the lake may be considered as partly allotrophic. The dead remains of the adjacent Angio-sperms as well as dung from domestic animals must provide an important food and energy source. Even with this additional source of material the lake can only be considered as oligotrophic to mesotrophic when one considers the biomass of material it supports. Table 5.5. shows the standing crops in a variety of lakes together with the biomasses of fish that these support.

Table 5.5. Relation between standing crops of fish and other organisms in various lakes.

Biomass of Benthos	Biomass of Fish	Ratio	Reference
5.2 g/m^2	1.2 g/m^2	4.3:1	HAYNE & BALL 1956
184 mg/m^2	62 mg/m^2	3 :1	SWINGLE & SMITH 1941
4.8 g/m^2	0.5 g/m^2	9 :1	JUDAY 1940
11 g/m^2	1.5 g/m^2	7 :1	ODUM 1957
10.9 g/m^2	4.9 g/m^2	2.1:1	MOORE et. al. 1934
130 mg/m^2			Meadow Lake

The estimate for the Meadow Lake shows that even at a comparatively low altitude (2,950 m.), with some organic enrichment, productivity is comparable with arctic lakes (GOLDMAN 1959, GESSNER 1959, LIVINGSTONE 1958). The aim in making this estimate of productivity was to assess the potential value as a fishery of any reservoir which was constructed in this area. A large reservoir is envisaged in the Panjshir Valley and although its primary purpose would be for irrigation and drinking water supply, there seems to be no reason why it should not be considered for fish production. This is especially worthy of consideration in an area where the diet is deficient in protein. It is difficult to extrapolate the results of this brief survey of three small lakes to give figures for potential fish yield of a Panjshir reservoir. It has been shown by CARLANDAR (1959) that there is no tendency for the standing crop to decrease with increase in size of lake. Based on this and the results from the Samir lakes, other high lakes and arctic lakes, it would appear that a reservoir in the Panjshir Valley could produce significant yields of fish.

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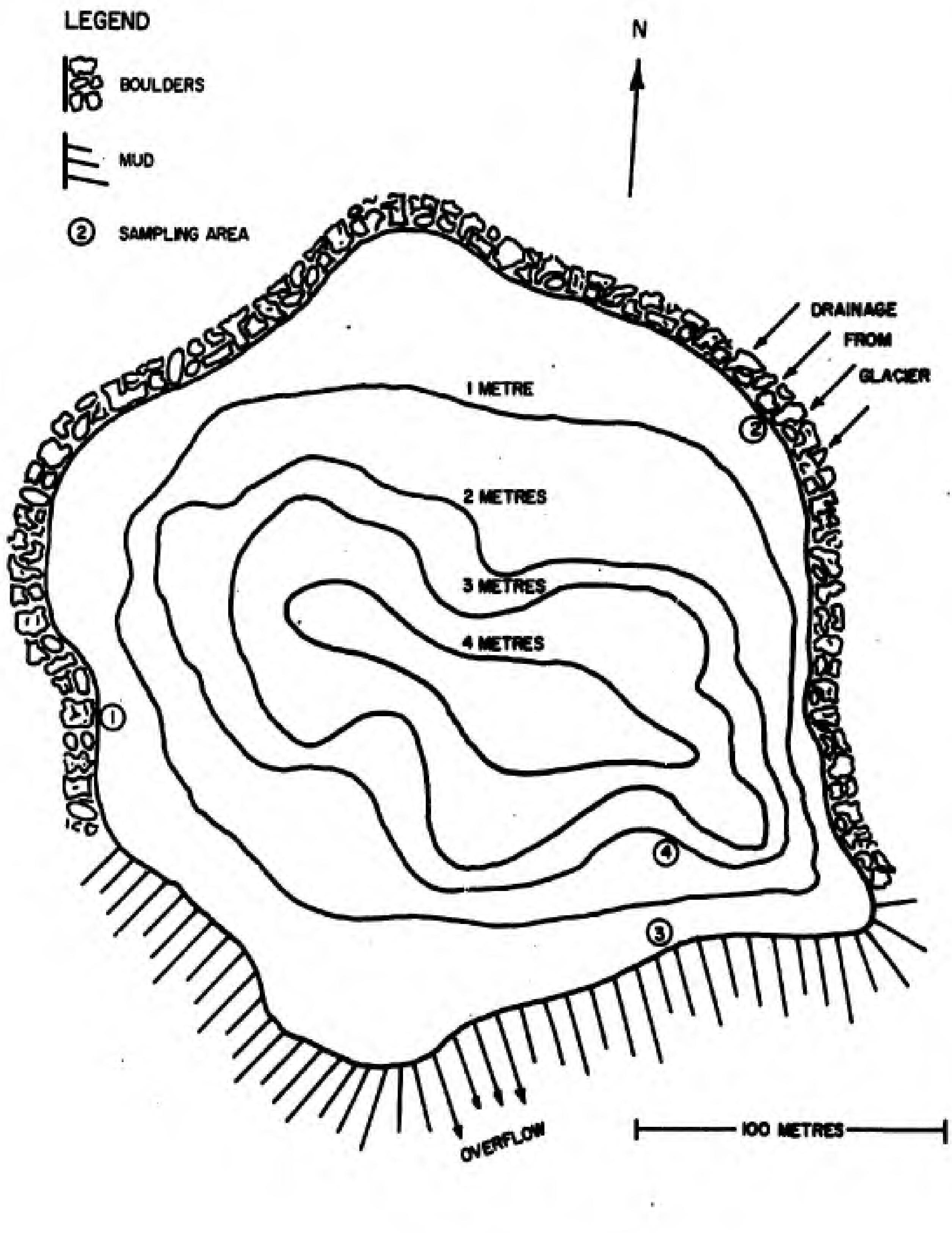

Fig.5.1. Approximate morphometry of Upper Newby's Lake.

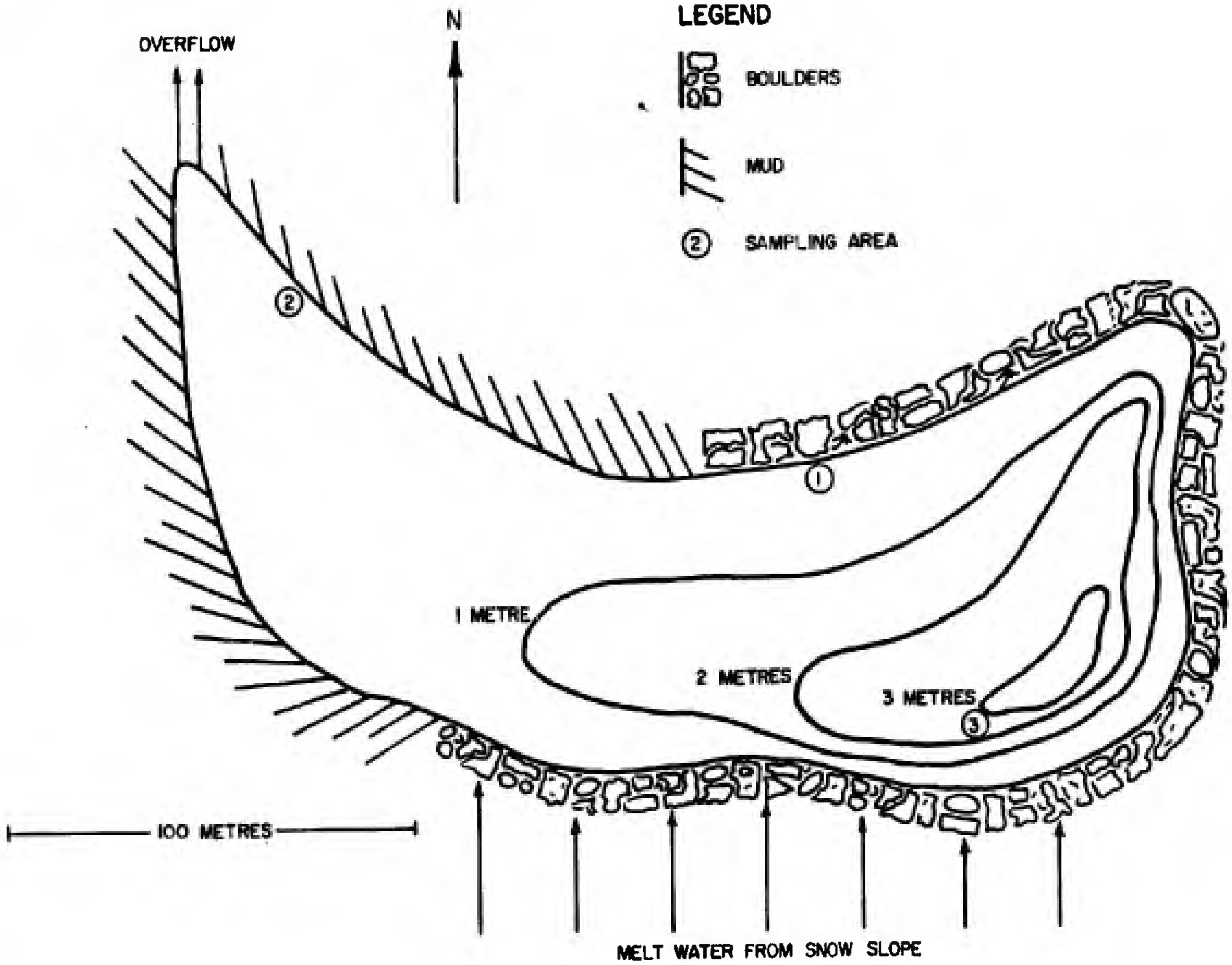

Fig.5.2. Approximate morphometry of Lower Newby's Lake.

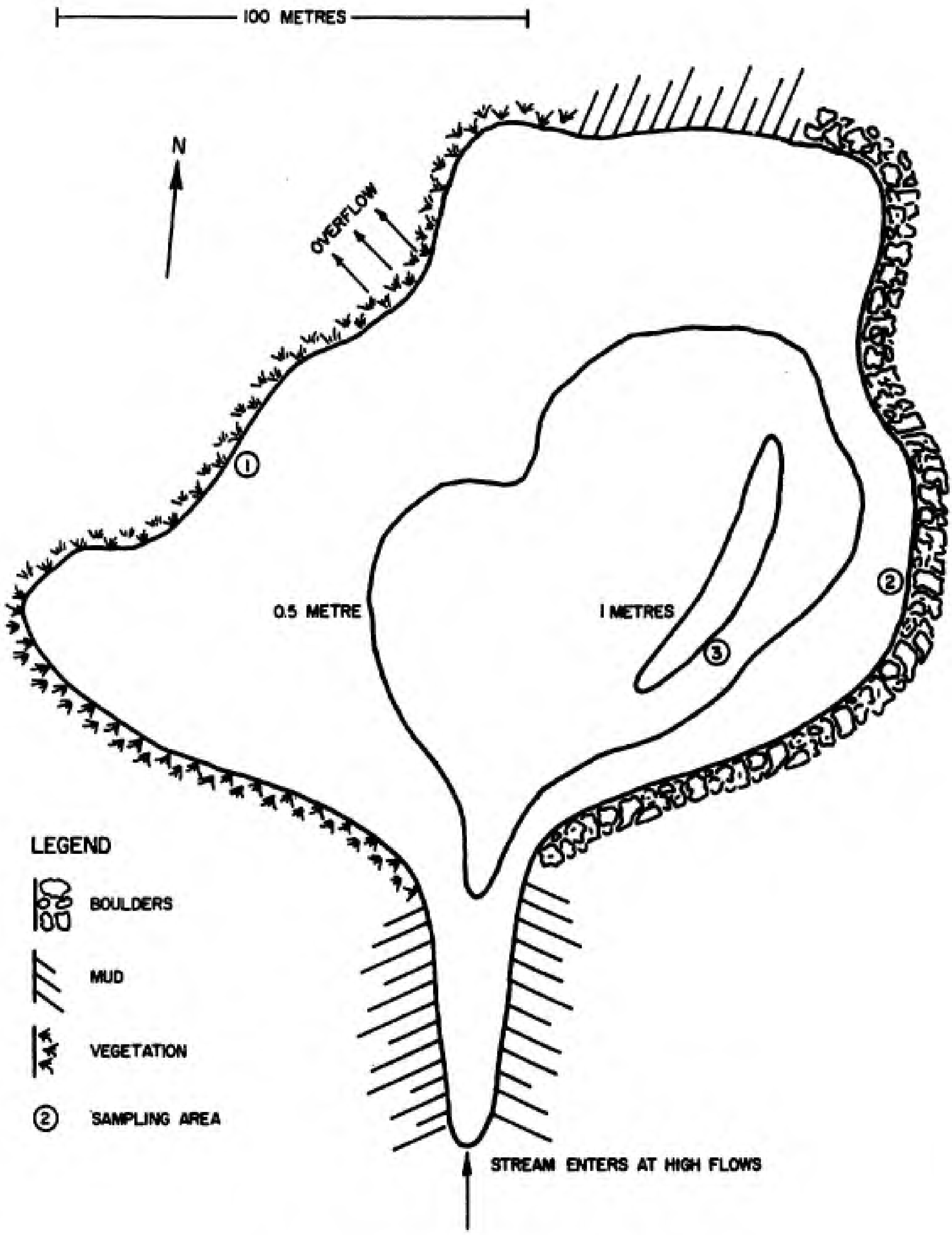

Fig.5.3. Approximate morphometry of Meadow Lake.

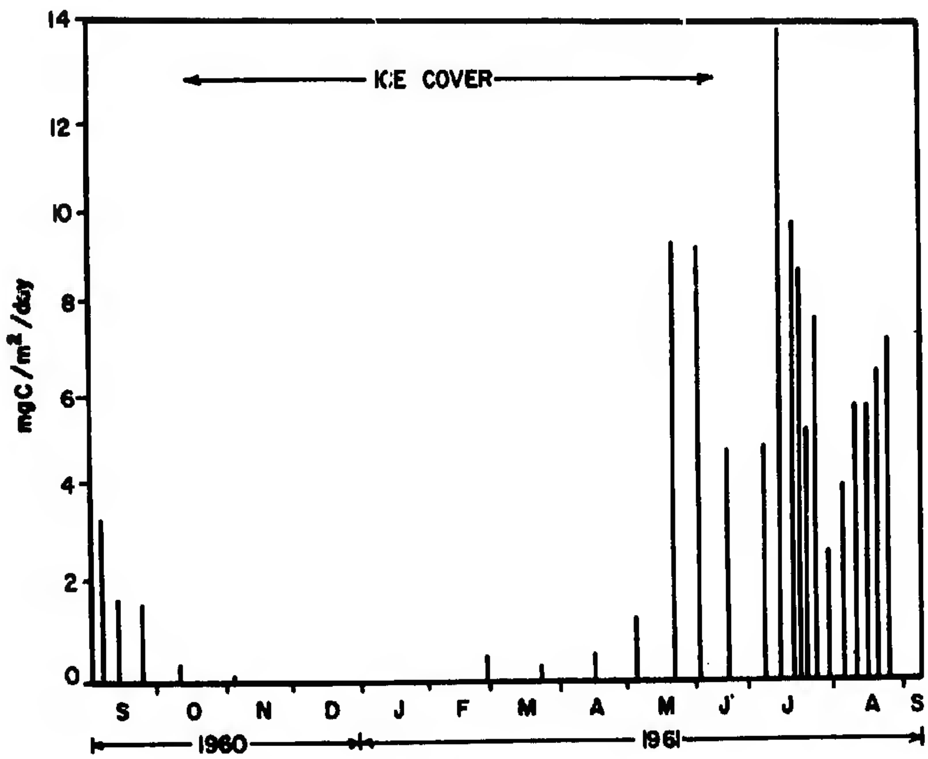

Fig.5.4. Primary productivity of an arctic lake under ice cover (HOBBIE 1962)

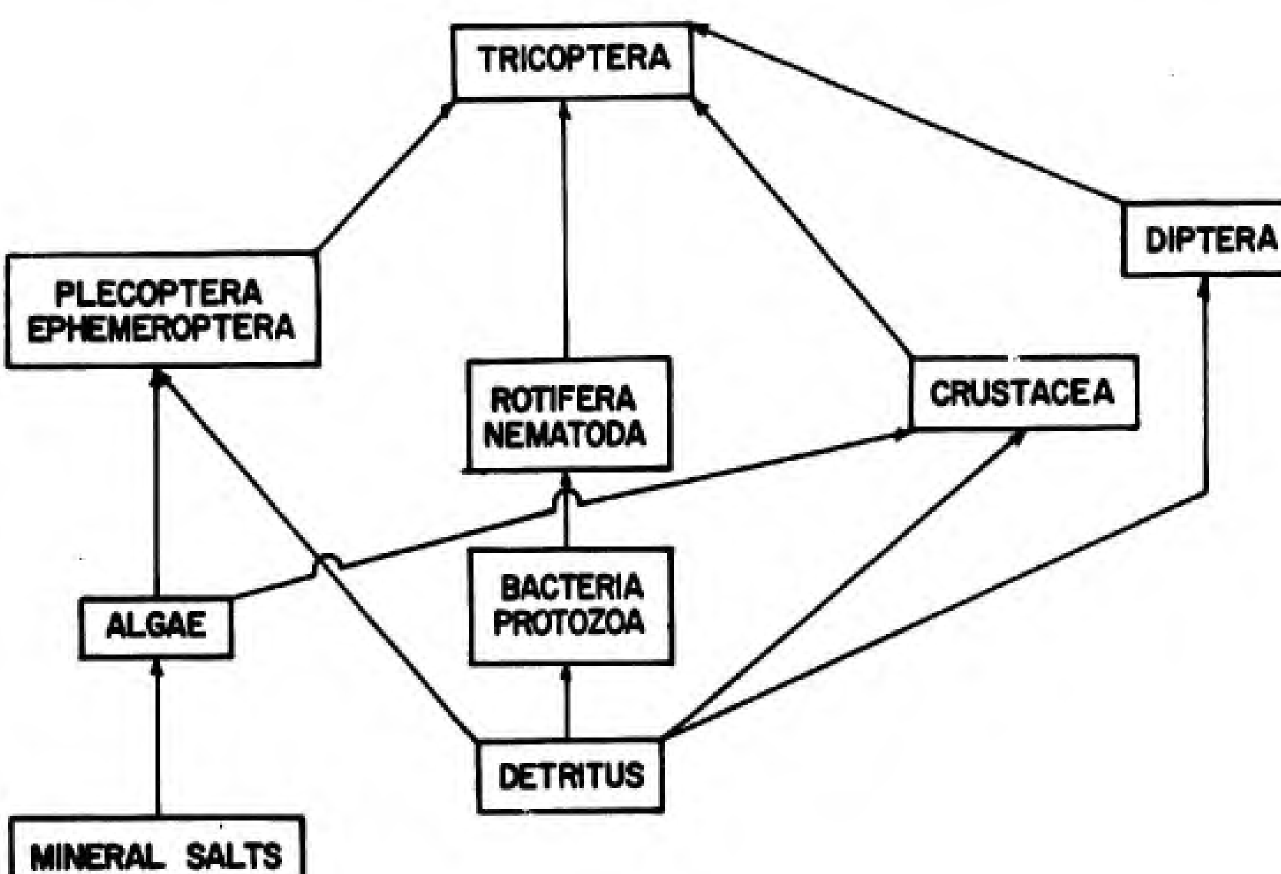

Fig.5.5. Postulated food web in Upper Newby's and Meadow Lakes.

BOTANY REPORT I

A General Account of High-Altitude Vegetation in the Samir Valley

by O. L. Gilbert

Summary

A general survey was carried out of vegetation occurring above 4200m in the Samir Valley. Despite the extreme nature of the environment & the effects of grazing the area supports a varied flora. A number of different types of habitat can be recognised on the basis of the plant associations they support; notably Snowpatch vegetation, Flushed grassland, Dry open grassland and Flushed ungrazed areas. The detailed composition of each association is noted together with a general list of other plants occurring in the area.

Introduction

At this height the environment contains many factors which are unfavourable to plant growth. A long cold winter, hot dry summer, unstable surfaces and a shortage of even immature soil (Table 6.1.) Climatic Date for N. Salang 35-22N. 69-03E. 5 yrs. 3,100 m.

	J	F	M	A	M	J	J	A	S	O	N	D
ppt. mm.	103.6	140.8	237.1	241.6	163.3	8.5	5.4	1.5	6.9	12.9	101.5	102.1
Mean monthly - temp. °C	10.5	-8.3	-4.1	-0.3	3.7	8.3	11.2	8.2	4.2	0.3	-4.3	-7.7

In addition, parts of the area are heavily grazed by large herds of fat tailed sheep and horses which are summered at this level. The most important of these factors would appear to be soilwater the distribution of which more or less controls the nature of the vegetation. Streamsides and flushed areas carry closed communities while elsewhere the plant cover is sparse and of an open nature. Superimposed on this pattern is the grazing factor, areas accessible to sheep are dominated by grasses, sedges and a few unpalatable plants while ungrazed sites are botanically much more varied with an abundance of tall herbs and scrub at the lower levels. Below 4,300m. there is little if any original vegetation left in the Samir Valley.

Snow Patch Vegetation 4,200-4,600m.

Around the lower margin of snow patches and beside the meltwater streams originating from them a most attractive community dominated by *Primula macrophylla* Don. (Fig. 6.5.) and *Ranunculus rufosepalus* Franch. can be found. There are about 5 constant species and Fig. 6.1. indicates their spatial relations.

The soil below snow patches is usually a deep very stoney silt, permanently waterlogged in summer. The *Primula* appears to be restricted to niches where its roots are continually irrigated with moving water at or near 0°C.

Flushed Grassland

A series of four structural benches cross the upper part of the Samir Valley. These have formed collecting grounds for silt and now appear as a chain of flat green meadows (up to 15 hectacres) on the floor of the narrow valley. They are receiving sites for large quantities of meltwater which stimulates the vegetation and is the reason why the shepherds bring their flocks up the valley as high as 4,200'

The wetter parts have a microtopography of hummocks and hollows up to 20 cm. high and 1m. across. These produce a strong pattern in the vegetation (Fig. 6.7.).

Hummock Spp.

Leontopodium leontopodinum (D.C.) Hand Mazz Sensu. K.H. Reching in Symbolae Afghanisae. (Fig. 6.3.)

Primula capitellata. Boiss.

Plantago genitanoides. S & S. var. alpina. (Borum) Pilg.e.descr.

Cerastium - large white flower

Hollow Spp.

Allium atrosanguineum. Schrenk.

Thalictrum alpinum L.

Carex c.f.melanantha. C.A.M.

Potentilla - large yellow flowers

Pedicularis rhinanthoides. Schrenk. Subsp.rotunda. Vued.

Another cause of pattern is Kobresia schoenoides Baech the dominant monocotelydon which in the dryer parts grows in well defined rings.

The performance of the sedge as measured by shoot density and production of inflorescences is much higher at the edge of the ring than in the middle which is selectively colonised. Fig. 6.2. Annual species of Veronica and Eremopoa grow only between the rings while Poa pratensis is more frequent within them.

Dry Open, Grazed hillsides

This is the main vegetation type below 4,200m. At this level snow patches have mostly disappeared by mid-June and severe summer droughting restricts diversity. The open grassland has varied dominants which include Koeleria cristata (L.) Pers. Poa araratica. Trautv. and Psathyrostachys caduca (Munro) Nevski together with many annuals and a high proportion of deep rooted Legumes which suggests that levels of available soil nitrogen may be important. At lower altitudes, (3,600 m.) extremely large perennials such as Ferula Jaeschkeana Vatke e. descr. and Rheum sp. produce 2-3m. tall inflorescences at irregular intervals (Fig. 6.4.). Corydalis moorcroftiana Wall which is unpalatable forms dense stands of its yellow flowers on certain dry slopes, while another grazing resistant herb is the spiney Astragalus minuto-foliolatus Wendelbo first discovered in Afghanistan in the previous year (Fig. 6.6.). The shepherds use it to make small fires at night.

Some other species found in this habitat were Chorispora macropoda Trautv.

Draba koeiei Rech.b. Oxytropis c.f. immersa (Baker) Bge. Poa bulbosa L. var. vivipara, Bromus gracillimus Bge., B.tomentosus. Trin., Eremopoa persica (Trin.) Roshev.var.songarica (Schrenk) Bor, Stipa pennata L. Bunium afghanicum Beauv.e.descr., Platyaenia lasiocarpa (Boiss.) Rech.f.et Riedl ssp incana and ssp. radiata. Trachydium depressum Boiss. Ephedra and Equisetum ramosissimum. Many centuries of over grazing by sheep and goats has greatly impoverished this habitat which must always have been in a delicate balance with the environment.

Flushed ungrazed areas

These are of restricted distribution but can be found as isolated patches where rills pass through scree slopes and beside the river. A lush growth of grasses and tall herbs develops which has a structure reminiscent of English haymeadows. Phleum alpinum L., Pleurospermum stylaris C.B. Clarke, Deschampsia koeleroides Regel and Poa alpina L. seem to be restricted to this habitat. Saxifraga hirculus L. was dominant in some areas.

Dry ungrazed

Of restricted occurence. Some of the best stands are to be found on cliff ledges or as isolated pockets in scree. Sedum crassipes K.K. F.and Thomas Nepeta subincisa Benth and Geranium pratense L. were constants, being joined locally by members of the Boraginaceae and Cystopteris fragilis (L.) Bernh. if suitable crevices were available.

Below 3,800m. Rosa scrub with Eremurus stenophyllus (Boiss. & Buhsc) Baker starts to appear on the steeper slopes.

Plants seen only above 4,500m.

Several plants seemed to be restricted to the highest ground where moraines, stone polygons and shattered rock alternate with late snow. Ermania flabellata (Regell) O.E. Schule, Androsace villosa L., Draba altaica (C.A.M.) Bge. and Ligusticum afghanicum Rech.f.e.descr. together with the snow patch vegetation represent the highest plants collected.

Special collections of Umbelliferae and Gramineae were made for Kew. All other material has been deposited at the Edinburgh Herbarium where work has started on preparing "Flora Iranica" which will include this part of Afghanistan. The identification was assisted by HEDGE and WENDELBO (1964).
The following plants not mentioned in the above account were collected in the Upper Samir Valley.

Edinburgh

Delphinium brunonianum Royle
Dianthus sp.
Astragalus spp.

Lomatogium sp.
Nepeta aff kohanica
Smelowskia calycina (Willd) C.A.M.
Gagea sp.
Luzula apicata L.
Rhynchospora sp.
Carex cf. melanantha C.A.M.

Kew

Gramineae

Agropyron canaliculatum Nevski
A. afghanicum. Meld
Agrostis olympica (Boiss) Bor.
A. canina. L.
Alopecurus arundinaceus Poir.
A. aequalis. Sobol.
A. himalaicus Hk. F.
Bromus oxydon Schrenk.
B. danthoniae Trin.
B. tectorum L.
Calamagrostis forsan sp. nov.
C. epigejos (L.) Roth
Colpodium himalaicum (Hk.f.) Bor.
Elymus dahuricus Turez.
Festuca rubra L.
F. ovina L.
Hordeum turkestanicum Nevski.
Koeleria glaucovirens Dom.
Leucopoa karatavica (Bgs.) V. Krecz. et. Bobr.
Melica jacquemontii Decne.
Poa dshilgensis Roshev.
Poa trivialis L.

Umbelliferae

Angelica sp. Not matched
Carum carvi L.
Hymenolaena aff. candollei (Wall.) D.C. Forsan sp. mov.
Pimpinella sp. not matched
Prangos pabularia Lindl.
Seseli sp. No fruit and not matched.
Zosima (Platytaenia) dichotoma Boiss.

Acknowledgements

My thanks are due to Ian Hedge of the Royal Botanic Garden, Edinburgh, for naming all families except for Umbelliferae and Gramineae. The latter groups were dealt with by J.P.M. Brenan and C.C. Townsend, Royal Botanic Gardens, Kew.

BOTANY REPORT II

Lichen Ecology in the Hindu Kush

by O.L. Gilbert.

Summary.

This report describes a survey of lichen ecology which was carried out over six weeks in the Upper Samir Valley. During this time observations were made on the lichen flora with the aim of discovering something about past movements of the glaciers. To do this satisfactorily, the total lichen flora between 4,270m (14,000 ft.) and 5,190m. (17,000 ft.) was investigated. This is reported on pages 1.5 and 1.6 of the Glaciology Report.

Results

Compared with an area of similar size in Britain, lichens were extremely scarce in both variety and amount. Less than 25 species were found, it being not unusual to examine several hundred square meters of rock without finding one.

Crustaceous growth forms were dominant (91%) about a quarter of them being squammulose while foliose species totalled only 9% and none were frutiose. This growth form spectrum is typical of dry arid climates (GALUN, 1964). The two foliose species were closely associated with melt water, Peltigera spuria being confined to low productivity grassland bordering melt water streams and Gyrophora reticulata to wet bedding planes on cliff faces or snow melt tracks down boulders. However, the rather extreme climatic conditions are unlikely to be directly responsible for the poor lichen flora as certain habitats such as old erratic boulders carried a lichen cover of up to 50% irrespective of aspect or altitude, and the lichen flora was no richer where the water regime was more favourable, i.e. near waterfalls or in stream gorges.

The factor which seemed to be controlling lichen distribution was one only met with in countries where long extensively dry periods alternate with occasional rain. Under these conditions chemical weathering mobilises any iron or manganese salts in the rocks which come to the surface and these form a thin dark brown coating which, because of its colour and shiney surface is known as desert varnish. (LAUDERMILH , 1931). The metamorphic rocks of Mir Samir are rich in these two metals and the varnish covers all stable screes, old moraines and rock outcrops producing a surface which lichens are unable to colonise. The mechanism of this factor could be either heavy metal toxicity - lichens are known to be sensitive to these elements, (RAISTRICK and GILBERT, 1963) - or it could be operating through the vitreous texture of the surface produced. This problem has not been resolved through it seems to operate at the establishment stage in the life cycle as it was frequently observed that lichens growing adjacent to desert varnish could spread on to it with no diminution in performance.

Lichen rich habitats are consequently those were desert varnish fails to develop. They include stream beds, exfoliated surfaces, the underside of overhangs and bird perching stones. The landscape is strewn with large erratic boulders about 10 feet high and these are the most productive sites. Although well coated with desert varnish this is absent from recently exfoliated surfaces which carry an attractive community of deep orange Xanthoria elegans, dark brown Lecidea atrobrunnea (Ram) Schaer and two cream coloured sqammulose Lecanoras, L.melanophthalma and L. muralis. These are the leading species of what appears to be the climax community on bare rock surfaces in this part of the Hindu Kush where the rocks range from slates through micaceous schists to garnetiferous gneiss. Schists which exfoliate more readily than the massive gneiss carry the most lichens.

A number of specialised habitats could be relied upon to produce single additional species. Thus the upper surface of submerged stones often had a black crust of Staurothele clopimi(Wahlenb) Th.Fr Lepraria incana was sometimes prominent in moist crevices near the base of sheltered cliffs, while a subspecies of the cosmopolitan Rhizocarpon geographicum was restricted to areas washed by snow melt. Terricolous lichens were rare, but the fine soil in the middle of stone polygons regularly produced Caloplaca citrina. Apparently its only habitat in the area. The altitudinal limits of all these lichens was determined by snow cover.

An examination of lichens on the moraines round the glaciers suggested that a very slow steady retreat had recently speeded up. The usual criteria of species number/uniform area and mean and maximum colony diameter were used in the investigation. During the studies the normal succession on gneiss was worked out. Afteralong period of slow chemical and physcial weathering which far exceeds the 13 years found by PALMER and MILLER (1961) in the Alps, Candelariella c. aurella pioneers the succession as lines of yellow apothecia developing along cracks, it is soon accompanied by Acarospora cf. rufa - alutacea which also favours the cracks. Xanthoria elegans and Lecidea austromongolica follow then a gradual build up which includes an Aspiscillia leads to the climax community. Lecanora melanophthalma and Lecidea atrobrunnea are the last to come in.

A surpirsing feature of the lichen flora was that at least half the species and possibly all the genera are in the British list. (JAMES, 1965). This is in sharp contrast to the flowering plants of the area, less than 5% of them being native in Britain. This must be taken as an expression of the cosmopolitan nature of many lichen species, though it should be noted that most showed minor differences in morphology from the populations in Western Europe.

Acknowledgement

My thanks are due to Mr. P.W. James, Mr. T.D. Swinscow and Dr. J. Poelt for helping with the identification of several species. All lichens have been deposited in the Newcastle University Herbarium.

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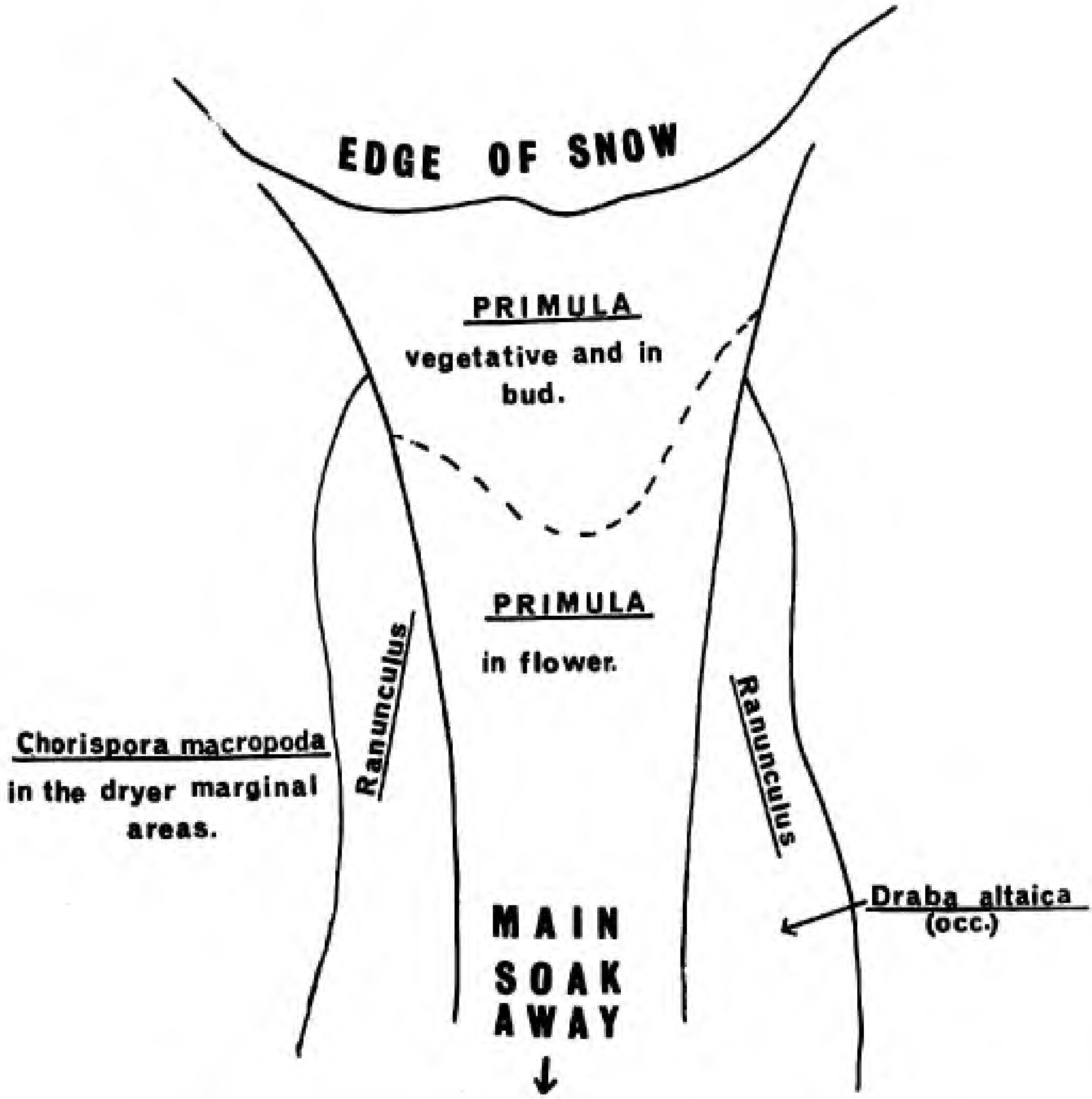

Fig.6.1. Snow-patch vegetation dominated by Primula macrocarpa and Ranunculus rufosepalus at 4,500m on Mir Samir, 27 July 1965.

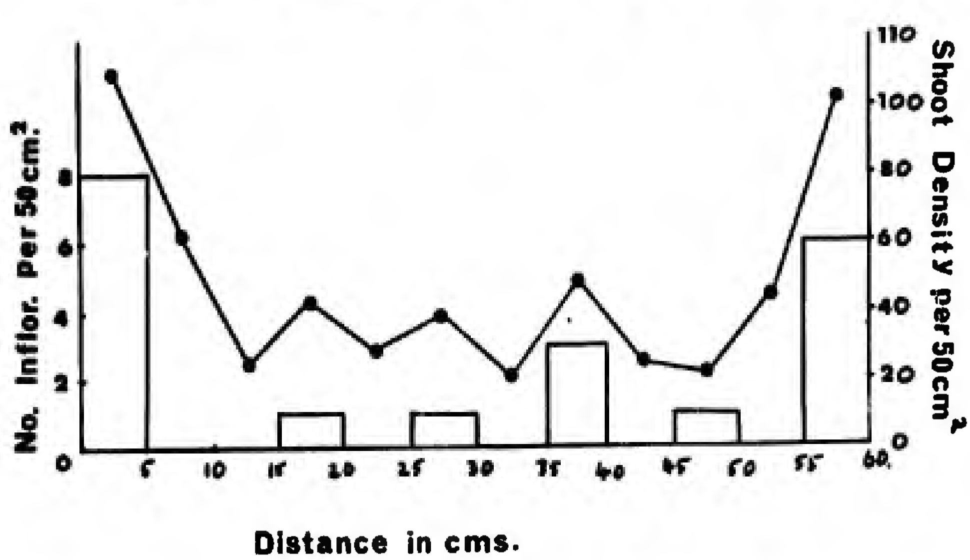

Fig.6.2. Diagram showing variations in performance across a Kobresia schoenoides 60cm in diameter. Shoot density (continuous line) and number of inflorescences (histogram) increase sharply at the advancing front.

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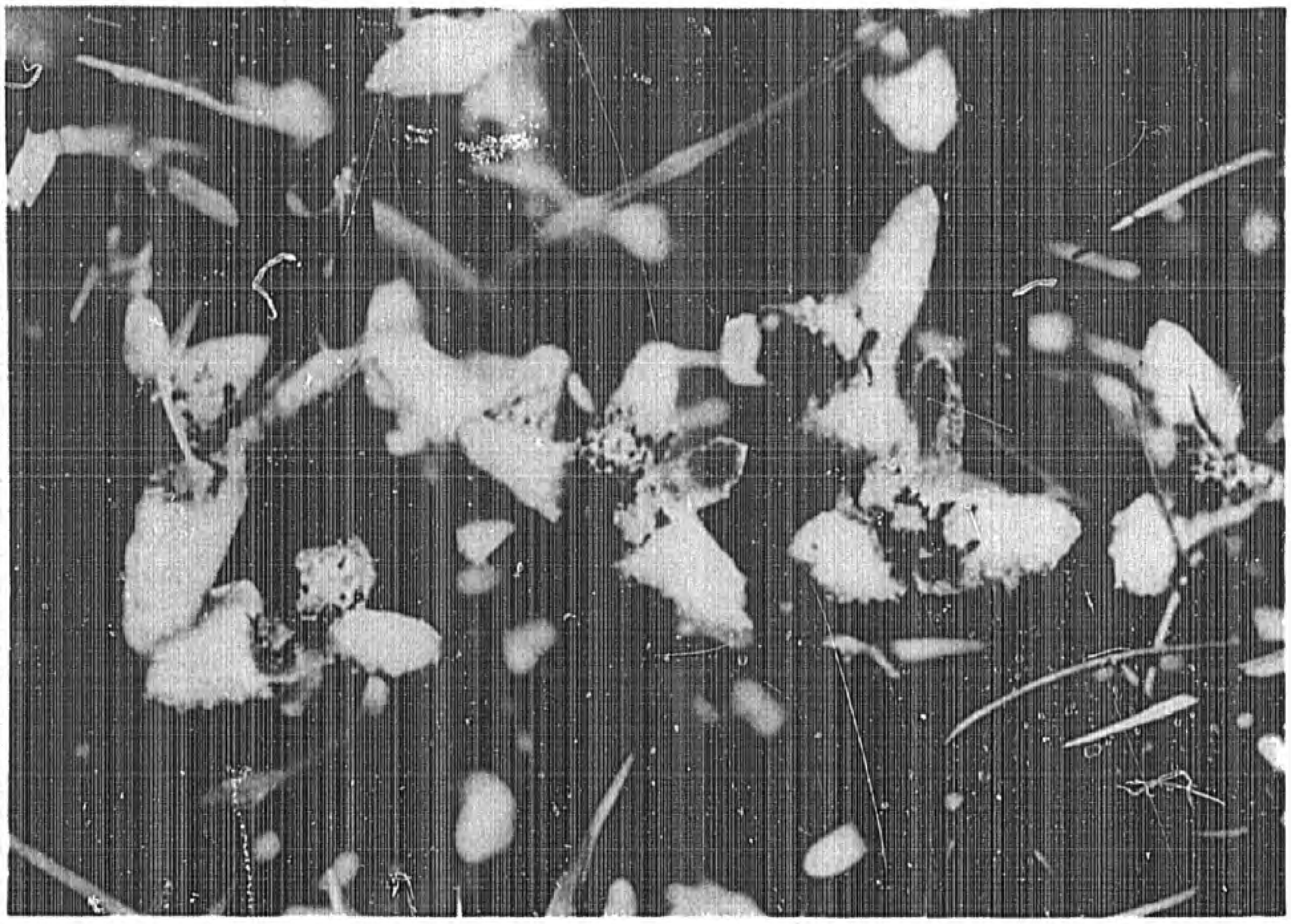

Fig.6.3. Leontopodium leontopodinum. "an edelweiss". Dense patches occur in the hummock/hollow grassland. Photo. Base Camp meadow. 18th August.

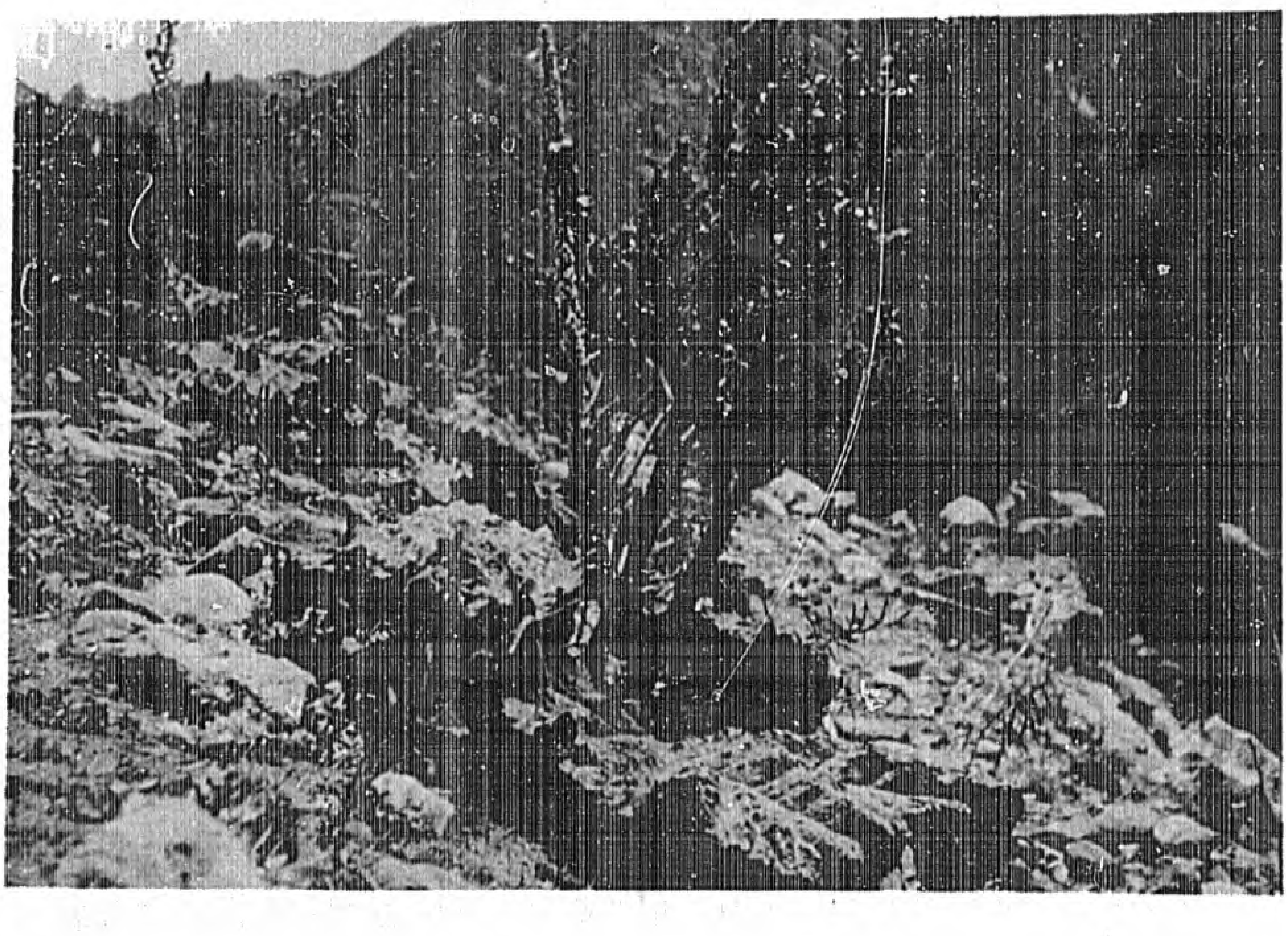

Fig.6.4. Rheum sp. "a rhubarb". Grows on dry hillsides below c. 3,600 m. Inflorescences may reach a height of seven feet. Verbascum thapus is also present. Photo. Samir Valley. 3rd August.

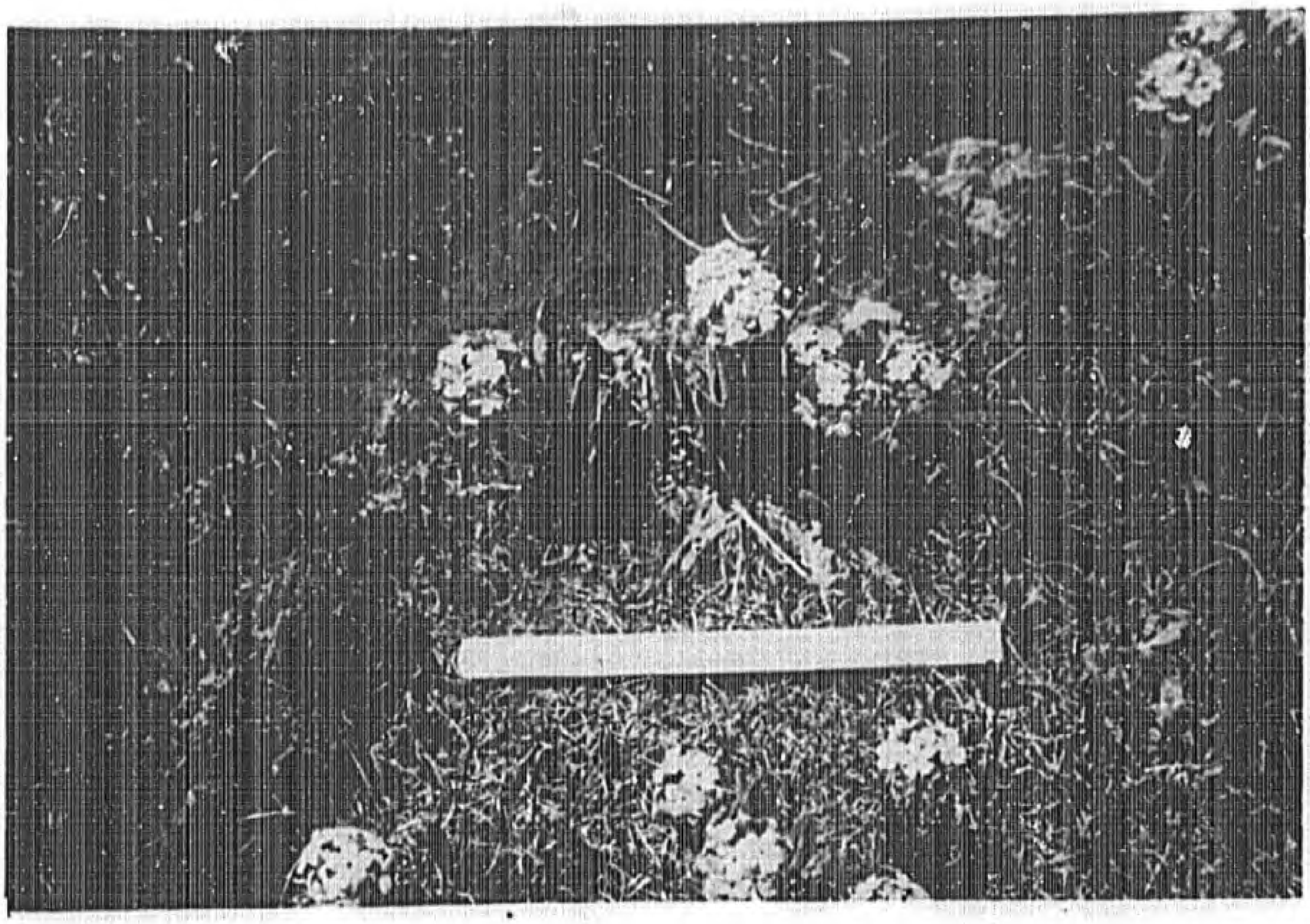

Fig.6.5. Snow patch vegetation dominated by Primula macrophylla.
Photo. near Newby's Lake.

Fig.6.6. A dry heavily grazed hillside near base camp. Corydalis moorcroftiana (in flower) and tufts of Astragalus minutofoliolatus survive due to unpalatability. Photo. 18th August

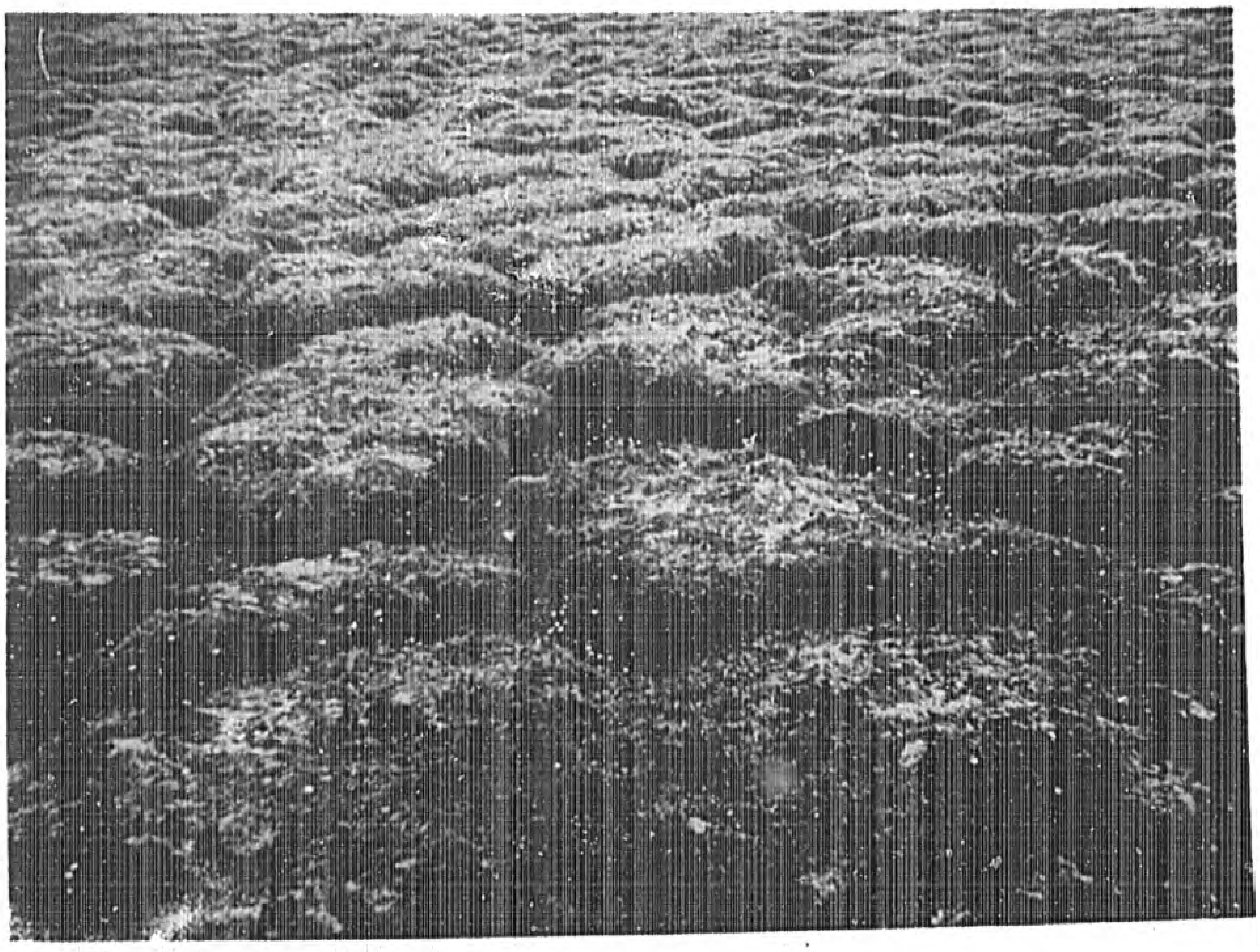

Fig.6.7. Hummock/hollow grassland on the wetter parts of base camp meadow. Photo. 18th August.

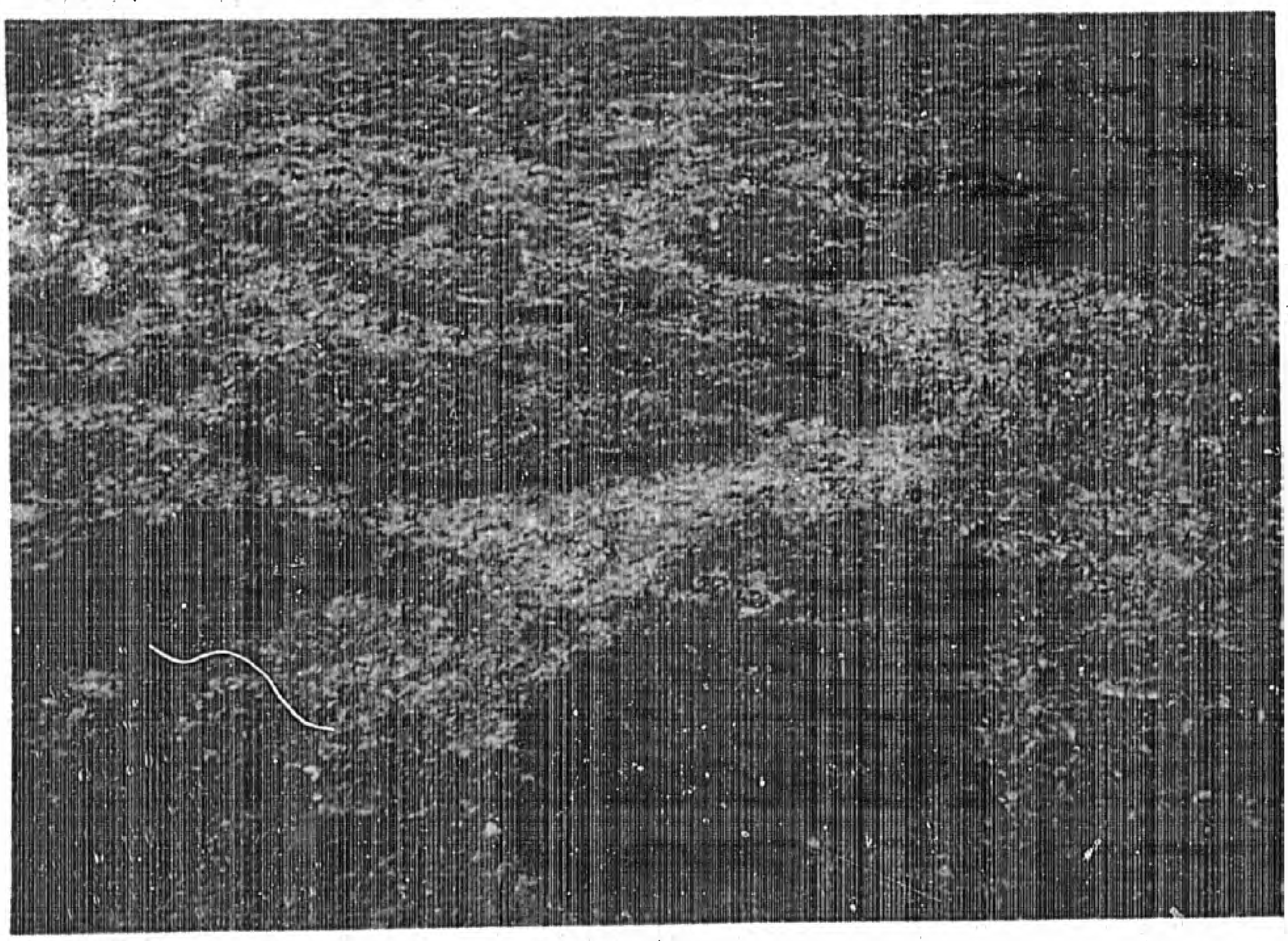

Fig.6.8. Kobresia schoenoides rings on the dryer parts of base camp meadow.

DENTAL-ANTHROPOLOGY REPORT

Some Anthropological Aspects of the Tajik Dentition

by A.D. Beynon

Summary

1. The ethnic origins, migrations and inter-relationships of the Afghan peoples are reviewed.
2. Some criteria utilised in dental anthropometric studies are presented, and their ethnological application discussed.
3. Macroscopic, photographic and selected dental and cranio-facial methods were used to determine the enthnological relationships of 33 Tajik males resident in Kaujon in the upper Panjshir valley.
4. The dental characteristics examined were (a) Dryopithecus pattern, (b) frequencies of occurence of Carabelli's tubercle, and shovel-shaped incisors, (c) maxillary arch shape, (d) tooth size.
5. Cranio-facial measurements were taken from which the cephalic indices of the subjects were calculated.
6. The mandibular molars were found to be highly modified in both components of the Dyropithecus pattern, and were also small in size. The crown morphology was characteristic of peoples of the Caucasoid race, an observation confirmed by the frequencies of occurrence of both Carabelli's tubercle, and shovel-shaped incisors.
7. These dental findings suggest that the Tajiks are a highly evolved people in a physical if not a social context.
8. The Tajiks have cephalic indices which are broadly divisible into two groups suggesting they they have incorporated or absorbed another caucasian sub-group.

Introduction

Afghanistan occupying the eastern half of the Iranian plateau, is contiguous with Persia which lies to the west. The division between the two countries is political rather than geographical, and it is not surprising to find similar peoples inhabiting the desert border areas of both countries. These people, the Tajiks, are thought to be limited to the western parts of Afghanistan (FURON, 1926; STAMP, 1962). The eastern border of Afghanistan is defined by mountain ranges which form a geographical barrier separating this country from Pakistan. The Hindu Kush mountain range which runs from east to west, divides the eastern part of Afghanistan into northern and southern plain regions. The central area of Afghanistan is occupied by the inhospitable Hazara region which is; an arid mountainous country about which, even today, little is known. (Figure 7.1.).

Afghanistan lies within the area originally colonised by Caucasians who are believed to have spread across from the West. Its situation at the eastern termination of the south-westerly prolongation of the Himalayan mountain chain (the Hindu Kush), has resulted in Afghanistan being repeatedly invaded by peoples from the North and West (FURON, 1926; STAMP, 1962; BRICE, 1966.) (Figure 7.2.).

Among the northern invaders were the Mongols, some of whom settled in the desolate Hazara region where their descendants now conduct a nomadic pastoral life. In additional Nordic peoples invaded the Iranian plateau where they are still represented in both the Kurds, who are found in Turkey and on the borders of Iran and Iraq; and in the Pathans, an independant tribe who live in the border region between Afghanistan and Pakistan. These people are a tall dolicho-cephalic group who are fairer in skin colouring than the Iranian plateau race.

Another physically distinct group is found in an isolated area, situated deep in the Hindu Kush, called Nuristan. This enclave lies to the north-east of Kabul. These Kaffirs differ markedly both physically and in social customs from other Afghan tribes, and indeed were only comparatively recently converted (by the sword) to Islam. These people are characterised by fair, or even red hair, and it is possible that they are descended from settlers of Bactrian greek origin left behind after the conquests of Alexander the Great.

North of the Hindu Kush are the plains associated with the Amu Darya (Oxus) river. To the west these lands are populated by the Turkomans, who are believed to be of Turkish origin; and to the east by the Badakhchs, about whose relationships little appears to be known.

Kabul, the capital, lies to the south of the Hindu Kush in the east of the country. The plains around Kabul which extend along the Kabul river towards

Pakistan, are inhabited by a heterogenous population containing many racial elements, including some Indians. One of the major factors which was presumably responsible for the siting of Kabul is its situation at the centre of several caravan routes passing to the west and north through the Hindu Kush (Figure 7.3.). Two of these routes pass to the north-east towards the Panjshir valley. The most important route swings to the north out of the Panjshir over the Kawak pass giving access to the upper Oxus river. The other route passes up the Panjshir valley over the Anjuman pass beside Nuristan, the home of the Kaffirs.

It is evident that the peoples of Afghanistan are varied and are drawn from widely differing ethnic stocks. The natural geographical divisions of the country have largely contained separate ethnic and cultural groups within specific areas, and this geographical isolation has enabled each sub-group to retain their peculiar racial characteristics. However, this picture, complicated as it is, may not be a full account.

According to current views (FURON, 1926; STAMP, 1962) the Panjshir should be populated by Pathans. In fact the valley is inhabited for most of its length by Tajiks, who are of Persian origin and who were formerly believed to be found only in Western Afghanistan. It is apparent that the foregoing account of the distribution of peoples in Afghanistan has not taken into account the possibilities of extension of certain groups into other areas; and that at least one of these groups, the Tajiks, are more widely distributed than was previously thought.

These events, - separation, migration and settlement must have occurred subsequently to the initial division of the human species into the three major ethnic groups-Caucasoids, Mongoloid and Negroid. One of the most fundamental ethnographic questions of all is the origin of the Caucasian race. COONS, (1962) considers that the Caucasoids arose in Western Asia. Since there are no major geographical barriers to the movement of men eastwards into Afghanistan it is possible that some of the present inhabitants may be directly descended from the archetypal Caucasoid people.

The significance of dental morphological characteristics has been recognised in evolutionary and ethnographic studies for many years. Many of the earlier hominoid specimens have been classified on the basis of dental morphology, and indeed the only records that exist of some specimens are the teeth which are the most durable components. Recently attention has been directed towards modifications in the teeth of modern man.

GREGORY (1916) first described the lower molar pattern of Dryopithecus, which was an early Primate widely distributed throughout Europe and Africa during the Miocene epoch. The mandibular molars are characterised by 5 cusps - mesio-lingual, mesio-buccal, disto-buccal, disto-lingual and distal; and the mesio-lingual cusp and the disto-buccal cusp are in broad contact, separating the mesio-buccal and disto-lingual cusps. Viewed from the lingual side the lingual fussure forms a Y shape (Fig. 7.4. See Fig. 7.7. for orientation).

GREGORY later showed that this pattern is characteristic of the lower molars of Simiidae and Hominidae. However, during the course of evolution this basic pattern has been modified, particularly in man to whom this discussion is subsequently limited. The degree of modification varies in individual teeth within the molar series, and indeed varies within individuals and ethnic groups.

The pattern consists of two components - 1. cusp number. 2. cuspal relationships. The pattern may be modified by a reduction in the number of cusps from 5 to 4; and/or the cuspal relationships may be altered i.e. the mesio-lingual/disto-buccal cusp contact may be lost (Fig. 7.4.).

HELLMAN (1928) classified these various modifications into a series progressing from primitive to modified forms. Although he treated the two components together, he regarded th cuspal relationship as being the more conservative feature. This assumption was not challenged for a number of years, and most subsequent authors followed his original classification.

However, in 1955 JORGENSEN questioned this observation when he pointed out that the two components are independent of one another and concluded that these elements should be treated separately. He studied the lower molar morphology of recent Danes and Dutchmen, and compared his results with published work on a variety of different ethnic groups which was then analysed according to his own views. JORGENSEN plotted his results in the form of a correlation diagram with the percentage frequency of Y pattern as the ordinate, and percentage frequency of 5 cusps as the abscissa. He found that individual molar teeth from each of the three major ethnic groups occupied specific areas (Fig. 7.6.). Although differences between racial groups have been recognised for many years, JORGENSEN's treatment and presentation of his results clearly distinguishes the three major racial groups.

This characterisation is of great value in comparative ethnographic studies, and it has been utilised in the present paper to determine the degree of purity of the Caucasian stock from which the Tajiks were derived.

The survey was carried out at the village of Kaujon in the Upper Panjshir valley. The village is isolated, being thirty miles distant from the termination of the motorable road. It is situated on the route leading into Nuristan, the home of the Kaffirs, which is only a single day's march away.

Materials and Methods

A total of 33 Tajik males were available for examination. The age of the subjects ranged from 7 to 65 years. This figure represents most of the male inhabitants, although it was not possible to establish the total population of the village. The women living in a strict Moslem community, were not available for dental examinations.

A number of morphological characteristics were studied by means of direct visual observation in the mouth (Fig. 7.7.). There were no facilities for taking dental impressions, and preparing study models. The characteristics studied were as follows:

1. Mandibular molars

   a) Dryopithecus pattern (cusp number and relationships)

   b) Tooth size:-

      i) The mesio-distal diameter (length) was measured between the contact points.

      ii) The bucco-lingual diameter (width) was the largest dimension measured in this direction.

2. Frequency of specialised morphological characters.

   a) Carabelli's Tubercle

   b) Shovel-shaped Incisors.

3. Shape of the maxillary arch.

   The width was measured from the centre of the palatal surfaces of the upper second molars, and the length from the centre of this transverse line to the palatal surfaces of the central incisor teeth. An estimate of the shape of the arch was derived from the formula:-

$$\frac{\text{length} \times 100}{\text{width}}$$

   This index will be referred to as the maxillary arch index.

4. Cephalic Index.

   This index was derived from the formula:-

$$\frac{\text{Maximum head width} \times 100}{\text{maximum head width}}$$

Results

In some cases teeth were not present due to extraction or non-eruption, or alternatively teeth were present but severe attrition, particularly in older subjects, had resulted in obliteration of occlusal morphological details. The numbers of teeth studied are summarised in Table 1.

In the first mandibular molar there was found to be a major difference in frequency of Dryopithecus pattern representation in the right and left sides. The Y pattern was altered to a greater extent than the cusp number which was the more conservative feature, since 5 cusps were found in over 90%

of the teeth examined.

In the second mandibular molar both components were modified to a much greater degree, both features being found in less than a quarter of the specimens. In this tooth however, the Y pattern rather than the cusp number was the more conservative feature.

In the third molar the Y pattern was completely lost whereas the five cusped form had increased in frequency relative to the second molar. These results are shown in table 7.1., and are plotted in diagramatic form in Figure 7.6.

The size of the mandibular molar teeth was found to vary within fairly wide limits, with the first molar tooth being the largest in both dimensions. The second molar tooth was the shortest in length, although in width larger than the third molar, which was intermediate in length between the first and third molar. Mean dimensions and standard deviations are shown in Table 7.2.

Among the special morphological features studied it was found that the frequency of shovel-shaped incisors was very low. In only one case (3%) was a strong shovel-shape found, and only four others showed a slight shovel-shape. This total comprised only 15% of the population studied. Severe attrition made identification of this feature difficult in older subjects. This was a particular problem with respect to Carabelli's tubercle, although indications ranging from double deep grooves to separate cusps were found in 14 (41%) of the subjects.

Measurements were taken and cephalic indices calculated for 32 subjects. There was found to be a remarkable spread ranging from 70.5 to 90.7. The mean was 86.7 with a standard deviation of 6.13. The individual results are shown on a histogram in Figure 7.8.

Variation was also found in arch width and length. The average arch length was 3.5 cm., and average arch width was 4.0 cm. The maxillary arch index was constructed to determine whether any relationship existed between the maxillary arch form and the cephalic indix - i.e. whether long arches accompanied long skulls etc. However, when individual cephalic and maxillary arch indices were compared there was found to be no such correlation.

Discussion

Although the study was carried out on a comparatively small number of individuals, the numbers presented include most of the male population of an isolated community and it is considered that a representative cross-section of the male population has been obtained.

The frequency of Y pattern and 5 cusps is of particular interest when plotted on the correlation diagram (after JORGENSEN 1955) and compared with the results of other studies on a variety of different ethnic groups.

Table 7.1. Frequency of different cuspal relationships, and numbers of cusps on lower molars of 34 Tajik males aged 7 - 65 years.

	M_3 SIN		M_2 SIN		M_1 SIN		M_1 DEX		M_2 DEX		M_3 DEX	
Total sample of teeth	20		27		29		30		26		16	
Total teeth with pattern visible	17		25		23		20		26		15	
Number and Percentage	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Y Pattern	-	-	5	20.0	12	52.2	15	75.0	5	19.3	-	-
+ Pattern	5	29.4	5	20.0	6	26.1	4	20.0	10	38.3	4	26.7
x Pattern	12	70.6	15	60.0	5	21.7	1	5.0	11	42.3	11	73.3
3 Cusps	-	-	1	4.0	-	-	-	-	-	-	-	-
4 Cusps	10	58.8	22	88.0	2	8.7	1	5.0	24	92.4	9	60.0
5 Cusps	7	41.2	2	8.0	21	91.3	19	95.0	2	7.6	6	40.0

Table 7.2. Mean sizes in mm. of lower molar teeth (left and right combined)

Size of sample	Tooth	Mesio distal (length)	Bucco-lingual (Width)
40	M 1 lower	10.9 ± 0.73	10.4 ± 0.54
35	M 2 lower	10.3 ± 0.59	10.0 ± 0.47
20	M 3 lower	10.6 ± 0.68	9.9 ± 0.46

Table 7.3. Mean mesio-distal lower molar tooth sizes (in mm.) in a variety of ethnic groups

LOWER MOLARS	Tajiks X	Amer. White 1	Amer. White 2	Lapps 2 X	Eskimo 2	Pecos Ind-ian 2	Java-nese 2 X	Aborig-ional 2	Bantu 2	Bush-men 2
M1	10.9	11.5	11.2	11.0	11.8	12.0	11.5	12.3	11.0	10.9
M2	10.3	10.7	10.7	10.5	11.4	11.4	10.9	12.5	11.0	10.6
M3	10.6	-	10.7	9.9	11.4	11.1	10.9	11.9	11.1	9.9

1 - SICHER (1965)

2 - Results of several studies summarised in SCOTT and SYMONS (1961)

X - Males only. All other measurements are from mixed samples.

The distribution corresponds in each tooth with the Caucasian group and is best illustrated by the second molar. Another significant feature is the greater degree of modification in the first and third molar compared with other Caucasians. This is most marked in the third molar where the Y pattern was not found. Most of the previous studies have been conducted on mixed male and female populations and it is possible that a sexual variation may exist; although MATSUDA (1961) in a study on Japanese school-children has found no significant sexual differences in pattern frequency in the first and second molars.

A comparison of mean tooth length with the results of other studies (Table 7.3.) shows that the Tajik first and second molars are smaller than any of the other groups examined. Another curious finding in this study alone, of the third molar being larger than the second, although still comparatively small, might suggest the retention of a primitive feature. DAHLBERG (1961) however, has shown that mandibular molars possessing 5 cusps tend to be larger than those with only 4. In this study it was found that almost half of the third molars were of the 5 cusped variety, whereas most of the second molars possessed only 4 cusps. In most of the other studies this was also found to be the case. It is surprising that this feature has not been found in other groups, although it is possible that in these cases the whole tooth has become diminished in size. If this does represent a primitive feature it is difficult to reconcile with the apparently high level of modification of the anterior molars.

One of the most interesting findings in this study is the remarkable degree of modification in both components of the Dryopithecus pattern, and also the apparent reduction in tooth size relative to all other Caucasoid groups so far studied. These observations raise the intriguing possibility that the Tajiks are highly evolved, at least as far as their dental morphological characteristics are concerned. This would appear to lend support to the idea that the Caucasoids did originate in Western Asia, and would indeed suggest that the Tajiks are close to the direct line of descent from the archetypal Caucasians, although a linear progression of modifications away from the original pattern cannot be proved.

The purely caucasoid character of the Tajik dentition suggested by the molar morphology is supported by the findings of very low frequencies of shovel-shaped incisors, which characterise mongoloids (HRDLICKA 1920); and the comparatively high frequency of Carabelli's tubercle which is characteristic of caucasoids (DAHLBERG 1963).

The cephalic index shows a remarkable range, and although the numbers involved in the study are small, there is an indication of two separate peaks; one between dolicho- and meso-cephalic and one in the brachycephalic range. This observation may indicate a possible intermingling of two caucasian groups. In view of the isolationist habits and specialised characteristics of the Kaffirs it is considered unlikely that intermarriage has taken place between these people and the Tajiks, despite their territorial proximity, and no evidence was apparent of any such unions. A more likely possibility is an intermingling of the dolicho-cephalic Pathans with the Tajiks. Culturally the two peoples are similar, both being mountain dwellers and horse-men; and it is possible that the Tajiks have displaced Pathans from the Panjshir valley.

Acknowledgements

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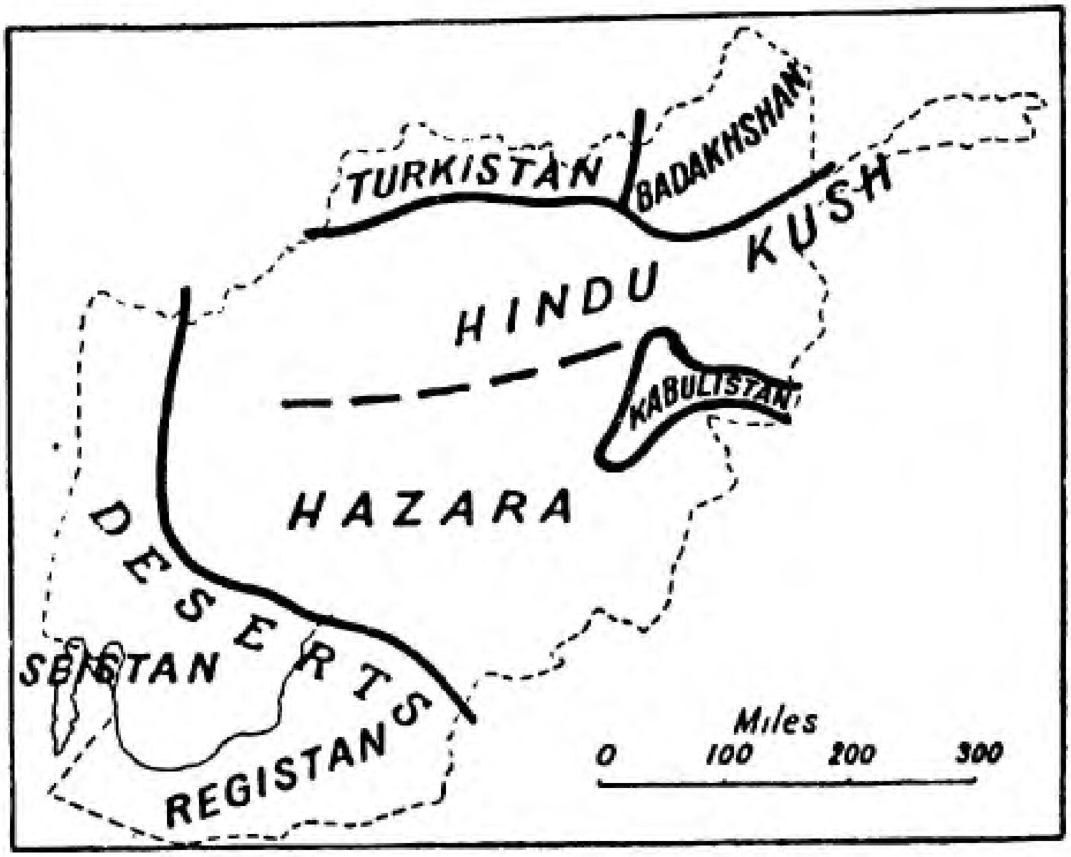

Fig.7.1. The natural regions of Afghanistan (STAMP 1962)

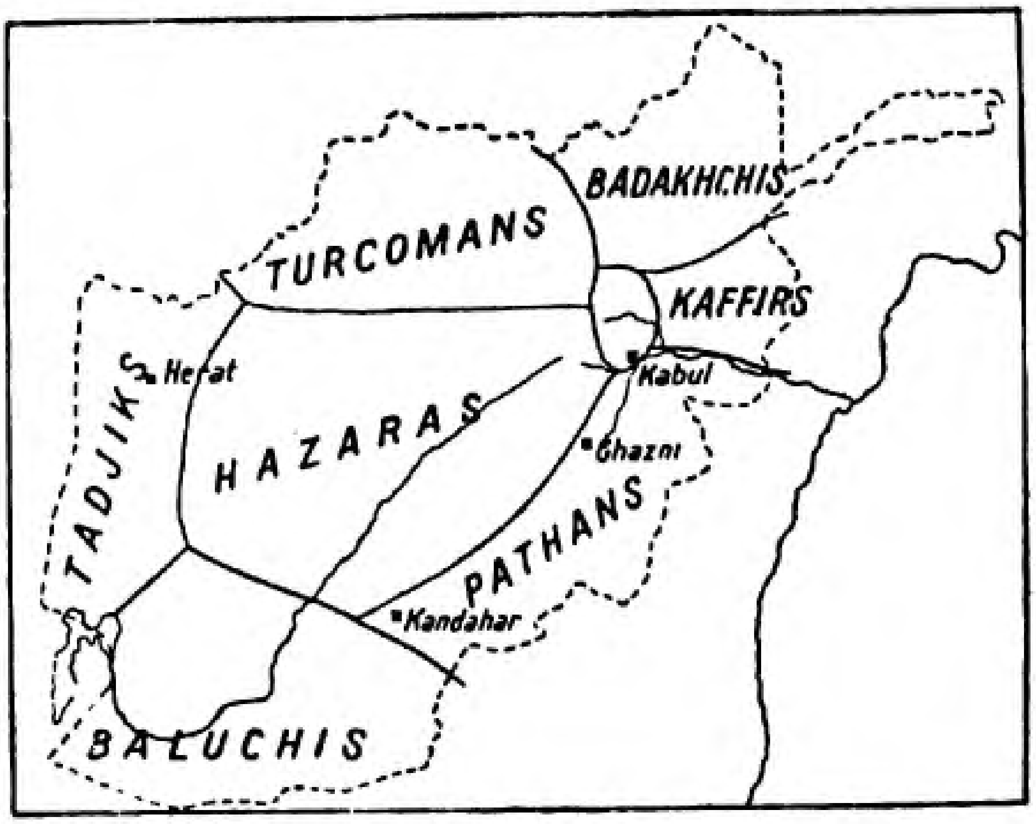

Fig. 7.2. The races of Afghanistan (STAMP 1962)

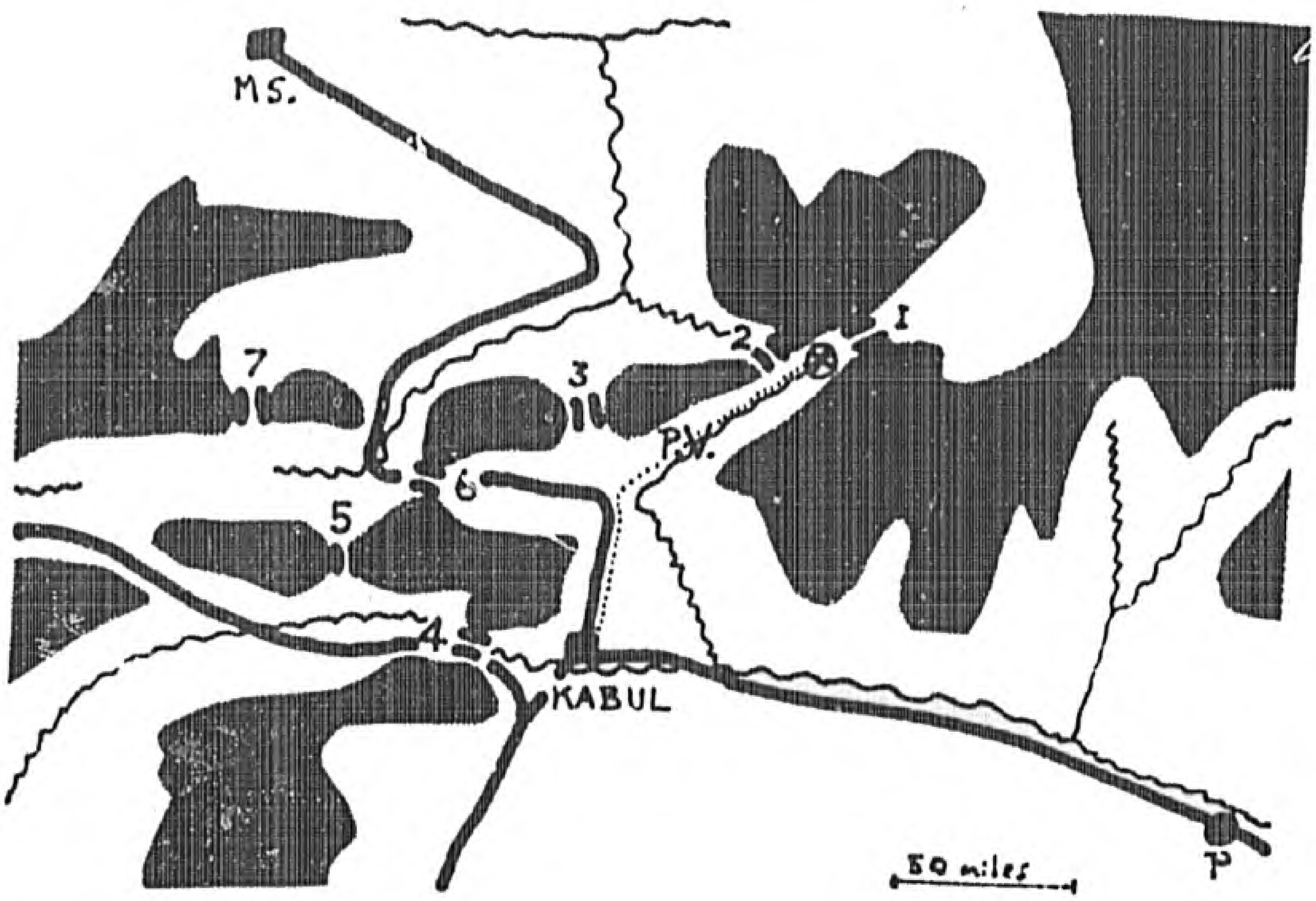

Fig.7.3. The relationships of the Panjshir valley, and the passes of the Hindu Kush (after Brice 1966).

1. Anjuman
2. Khawak
3. Salang
4. Unai
5. Hajigak
6. Shibar
7. Ak Robat

⊗ Kaujon

PV = Panjshir Valley
M.S = Mazar-I-Sharif
P = Peshawar

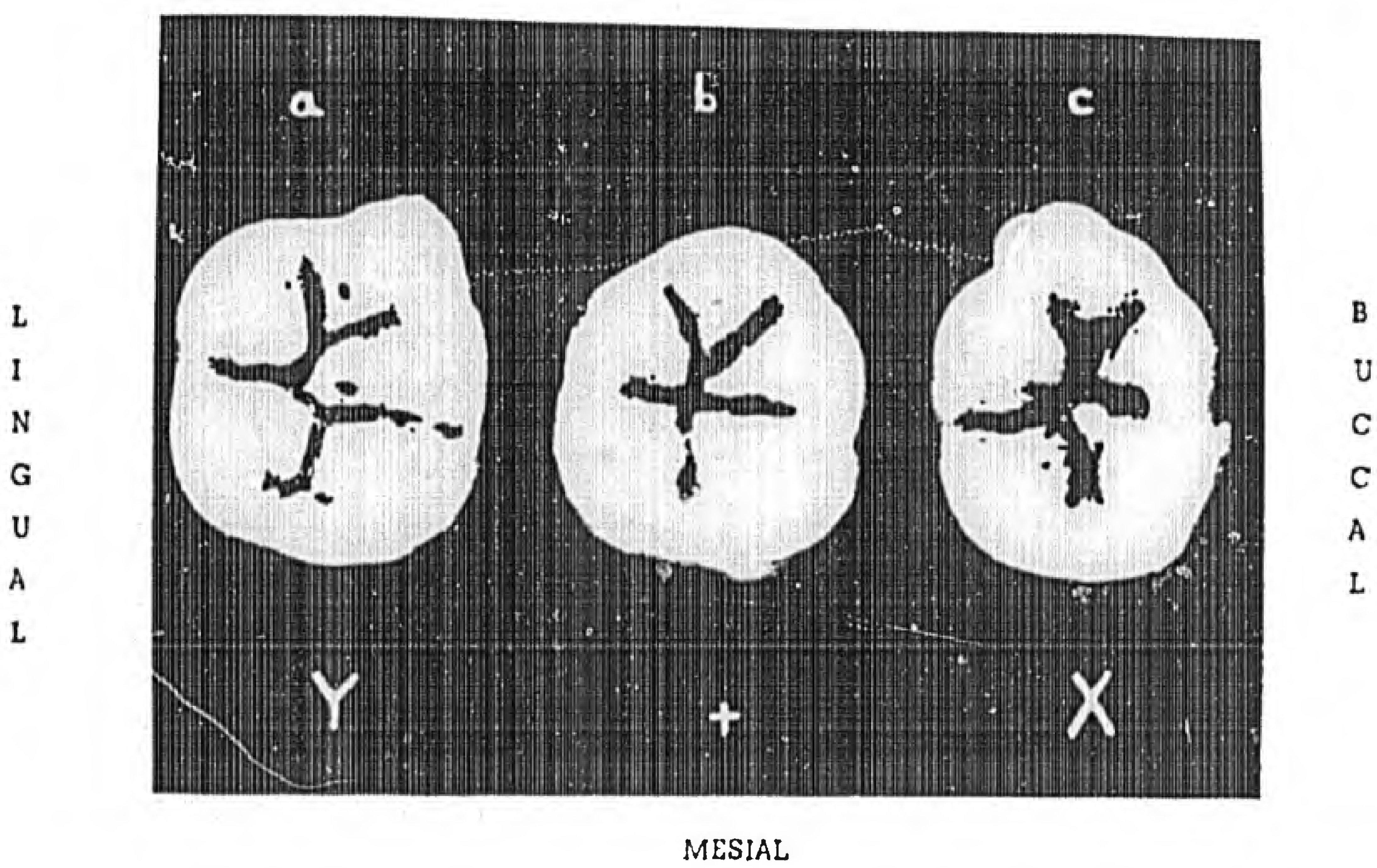

Fig.7.4. Specimens of three five-cusped mandibular left first molars, showing changes in their cuspal relationships.

(a) Shows the original Dryopithecus pattern, with the mesio-lingual cusp in broad contact with the disto-buccal cusp.

(b)and (c) show changes through point contact of the 4 central cusps (+) to a reversed relationship (x) with the mesio-buccal cusp in contact with the disto-lingual cusp.

Fig.7.5. A typical Tajik male.

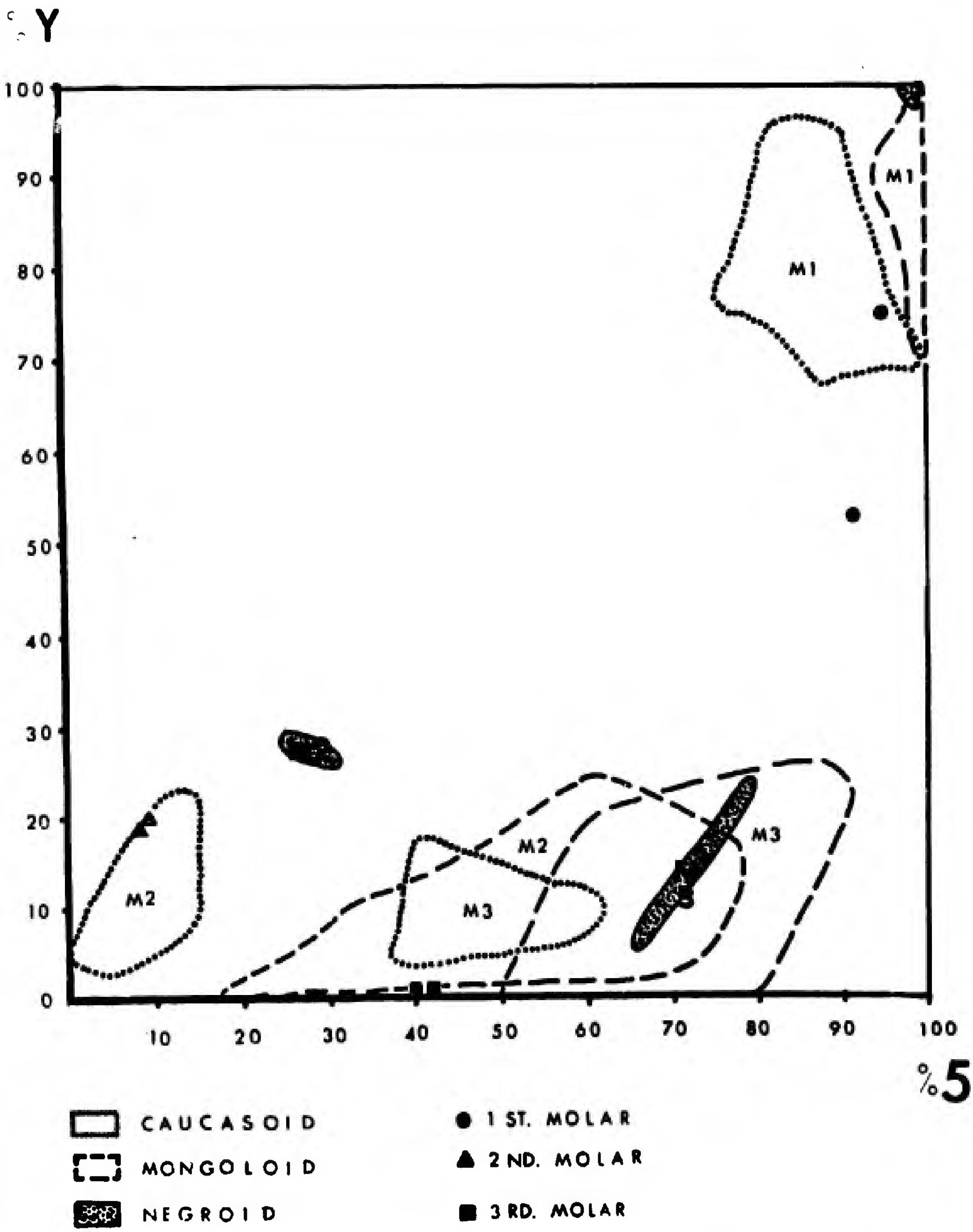

Fig.7.6. Correlation diagram showing the proportionate frequency of Y pattern and 5 cusps on the lower molars in different human populations (after JORGENSEN 1955). Mean values for each Tajik molar are plotted on the diagram.

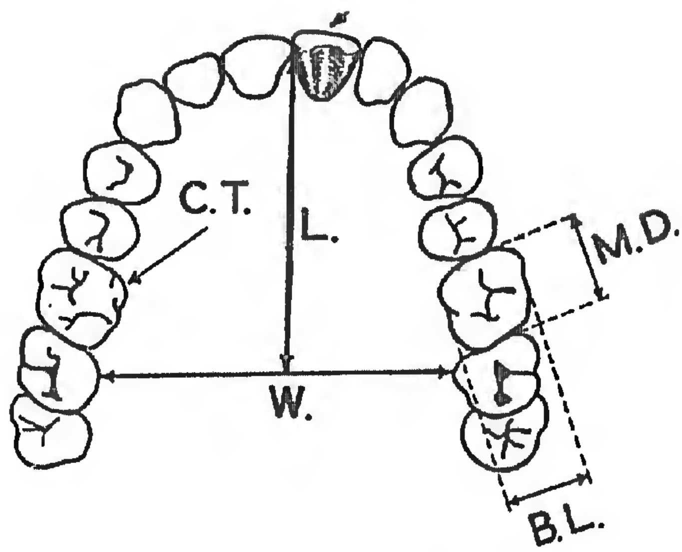

Fig.7.7 This diagram illustrates the direction of measurements recorded and the location of specialised morphological characters.

M.D. - Mesio-distal tooth dimension (length)

B.L. - Bucco-lingual tooth dimension (width)

W. - Minimum width between the palatal surfaces of the upper record permanent molars.

L. - Length of the upper arch measured between the centre of the arch transection (W) and the palatal surfaces of the central incisor teeth.

C.T. - Carabelli's tubercle, which is a supernumary cusp on the lingual surface of the mesio-lingual cusp of the maxillary molars.

S.I. - Shovel-shaped incisors. These teeth are characterised by marked development of the lateral marginal ridges.

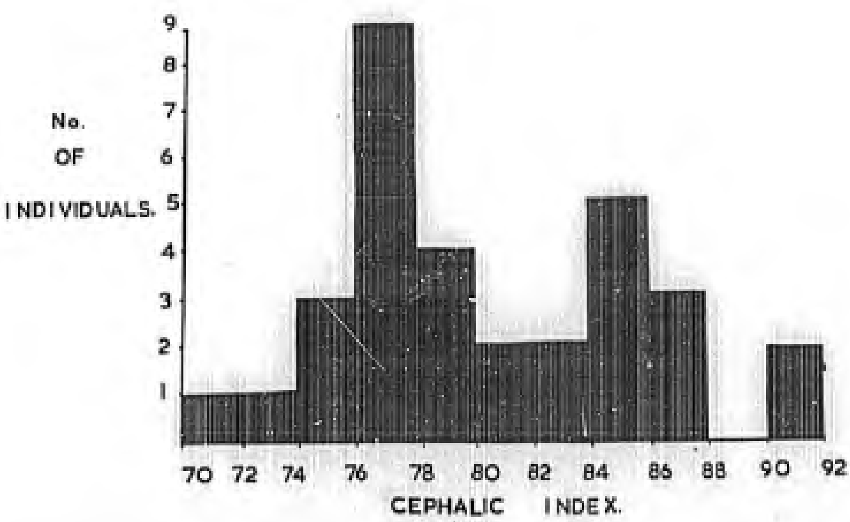

Fig.7.8. Histogram of cephalic indices

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LAND USE REPORT

A Survey of Land Use in the Upper Panjshir Valley

by H. Horsley.

Summary.

A survey was made of land use around the village of Kaujan in the Upper Panjshir Valley. This is a typical village in the Hindu Kush and many of the problems there are typical of the region. The Panjshir Valley around Kaujan supports a population of sedentary Tajiks and nomadic Pathans. These two groups are complementary rather than in competition. The Tajiks cultivate the small areas of arable land, producing mainly wheat, barley and broad beans. These crops provide the basic food which is supplemented by a number of smaller crops, some wild food (Alluim and Rheum) and meat from flocks of goats, sheep and cattle. The Pathans inhabit the valley only in the summer months when they use the high level pastures for their large flocks of sheep and goats. In the winter they move down to the plains near Charikar. Economically the Pathans are dominant although they rely on the Tajiks for their cereals.

The extreme nature of the climate places a severe restriction on the population that the Valley can support. There is a very short growing season separating the long cold winters. No precipitation falls during the growing season so all the arable land must be irrigated. The topography does not lend itself to agriculture or irrigation.

Because of a slight improvement in medical services, the population of the Panjshir Valley has begun to increase. The Tajiks practise the Moslem custom of male inheritance so that the fields are being split up into smaller, less efficient units. Remedial measures are urgently needed such as a reduction in disease of crops and an improvement in soil condition.

Introduction

Though occasional references have been made by explorers to the crops grown and techniques of cultivation in the Hindu Kush no comprehensive survey of Land Use in this region has been published. The Upper Panshjir is interesting not merely because of the extremely limiting environment but also because of the contrast in economy between the sedentary Tajik population and the nomadic Pathans.

Many problems arose in making the survey. Because of the unavoidably late decision to study an area in Afghanistan rather than in Chitral the expedition was unable to procure the services of a qualified interpreter. No maps of the area were available at the time the survey was made, but these are becoming available with aid from a U.N. team. Climatic statistics are inadequate and it was impossible to obtain reliable information on crop yields.

The main aims of this survey were however to examine the relationship between population and land use, to describe the various types of land use and techniques of cultivation and to determine the factors delimiting the various areas of land use. This information is interesting both purely academically, and for the contribution it may make to an understanding of the problems of development of a large area of Afghanistan with which Kaujan shares certain basic characteristics.

Physical Background

The village of Kaujan lies at an altitude of approximately 9,000' in the Upper Panjshir Valley. It stands on a cliff on the northwestern bank of the river near its confluence with the Samir. (Fig. 8.1.). This small outcrop of rock, useless for agriculture has made an excellent defensive site for the settlement. Most important has been the site which the outcrop offered for bridging the Panjshir, giving the village access to the high pastures of the Samir valley.

The main fields of the village lie in three large embayments of river terrace material to the north of the Panjshir. Smaller fields are situated both along the valley of the Samir and that of the Kaujan.

The climate of the area is hardly conducive to agriculture, summer rainfall is almost unknown as the winds are from the north. Most precipitation is in the form of winter snowfall. Snow may lie from November to March and reach over six feet during January and February. Late spring frosts make fruit growing, such as is found in the lower Panjshir, impossible in Kaujan. On the higher fields the growing season is less than a hundred days and the early onset of winter may seriously affect crop yields. Insolation is very high during the summer though air temperatures rarely rise above 65°F. Low air temperatures are a result of two factors, the rarified atmosphere, and rapid re-radiation of heat during the night.

The Panjshir rises near the Anjuman Pass some 70 miles to the north of Kaujan. It is fed by glaciers and snowfields and flows south to join the Indus. Though the regime of the river shows a marked spring maximum it provides sufficient water throughout the year to irrigate all the cultivated lands in this part of its course.

Metamorphic rocks of various ages dominate the geology of the area but little is known of its detail. The most extensive soils are of fluvial origin, though the processes of nivation and solifluction have produced steep patches of elemental soil which are cultivated even at altitudes of 10,000'. The organic content of the soil is low for manuring is insufficient. Soil structure is also poor for soil organisms do not thrive under arid or cold conditions. Though the soil is very thin, the plant life does not indicate any marked mineral deficiencies.

Cultural Background

The sedentary Tajiks are thought to have been the original population of the region. They make up the permanent population of Kaujan village and pursue both agricultural and pastoral activities. The village has over 130 people, they live in two storey dwellings of earth and stone. Though the use of earth depletes the soil, alternative materials are lacking, whilst thick earth and stone walls possess enviable insulating qualities. During the winter livestock are housed in the lower storey which is also used for grain storage. The upper storey provides living quarters, whilst the roof is used to store winter fodder and fuel.

The fields of the village are held by individuals. As the fields have been created piecemeal, those of each holding tend to be scattered. Problems created by this scatter are exacerbated by the Moslem customs of inheritance, holdings being split equally among sons. This custom is perhaps understandable in an economy where there is no alternative to agricultural employment. As there are great variations in the quality of the land in Kaujan not only do the holdings become smaller with each generation but the fields also become smaller, for individual fields may be split among sons. The total result is a network of scattered fields seldom larger than half an acre.

Though not claiming any exclusive right to the pastures of the Samir valley the Tajiks often reduce the pastoral area by extending the cultivated area, a necessary process where holdings tend to become smaller with each generation.

The Pathans are a nomadic people, typical of nomads in south west Asia, they alternate between the rich summer pastures of the mountains and the winter pastures of the semi-arid plains. These Kuchi Pathans spend winter on the plateau between Charikar and Jelalabad and move during summer to the high pastures of the Samir valley. A pastoral people, they are economically dominant and obtain their staple diet, wheat, by trading.

The Cultivated Area

The total cultivated area of Kaujan village amounts to little more than ½ sq. mile. (Fig. 8.2.). The fields vary from 9,000 to 10,500' and can be divided into two types. The most productive fields lie in the Panjshir valley below 9,200'. Here fields are larger, soils are better developed, and winter is less severe than on fields at higher altitudes. The fields of the Samir and Kaujan valleys are very small, often only a few square yards in area and where possible are on south facing slopes.

Excessive slope and lack of soil are the major factors limiting the cultivated area. The lower Samir valley contains large areas where steep gradients have prevented the developement of agriculture for lack of soil. Extension of the cultivated area beyond Sanjak has been prevented both by excessive slopes and by the length of winter.

The range of crops is restricted climatically. Only three major crops were being cultivated in 1965, wheat, barley, and broad beans. In years when spring is early Indian corn can also be grown.* Wheat the staple diet of the population occupies over half the cultivated land. In the lower fields the proportion is less for wheat can be grown successfully at higher atltiudes where the growing season is shorter. The dominance of wheat derives basically from this short growing season, though it also provides a balance between protein and carbohydrate in the diet. Unfortunately grain yields in the village are liable to violent fluctuations as bunt often affects the crops.

Barley is the second crop in years when corn is not grown. It occupies almost one quarter of the land and is grown mainly to feed to livestock. Broad beans the third crop of the region occupies one fifth of the land. A good rotation crop it thrives in low spring temperatures and provides both fodder and food. Rarely eaten as a vegetable, beans are usually mixed with the wheat and made into flour.

* For altitudinal limits of crop growth see Table 8.1.

Table 8.1. Altitudinal limits of crop growth

CROP	LIMIT AS FOUND BY HUMLUM (1959)	LIMIT IN PANJSHIR	LOCATION IN PANJSHIR
Barley	3,400m	3,350m	Nr. Sanjak
Maize	2,600m	2,250m	Dasht-i-Revat
Rice	2,580m	------	
Spring Wheat	3,300m	3,300m	Nr. Sanjak
Winter Wheat	2,800m	------	
Apricots	2,410m	2,600m	Shanaiz
Mulberries	2,400m	2,250m	Dasht-i-Revat
Walnuts	2,450m	2,250m	Dasht-i-Revat
Beans	3,100m	3,200m	Nr. Serband
Ervum Lans	2,800m	3,200m	Nr. Serband
Peas	3,150m	2,750m	Kaujan
Potatoes	2,600m	2,250m	Dasht-i-Revat
Tobacco	2,600m	2,750m	Kaujan

Minor crops such as peas and a lentil (Ervum Lens) are often sown with grain grops. A tobacco used as a stimulant is also grown. Timber may also be regarded as a crop in Kaujan though it does not compete with other crops for the use of land. Poplar is favoured because of its rapid rate of growth and its tolerance of moist root conditions. Grown on gravel patches near the river, the trees attract soil organisms increase silting and speed the development of an agricultural soil. Timber is needed for roof construction, bridge building and for making agricultural implements; though poplar is not really durable the low humidity and temperatures prevent rapid deterioration. Little timber is used for fuel. Dung is the main source of fuel, and bracken is also gathered in the mountains.

Fields are delimited by stone walls constructed during the process of clearing the fields. The building of stone walls serves as the basis of terracing and also prevents livestock entering the fields.

The lack of summer precipitation makes irrigation essential. All the irrigated lands are cultivated, there are no artificial pastures as described by BARTH (1956) in Kohistan. The means of irrigation is simple, water drawn off from the river is carried above the fields in canals which follow the contours. The canals are breached above the fields and the water flows across the fields down the hillsides. The highest irrigation channel begins at over 10,000' in the Samir valley. In the main Panjshir valley the gradient is relatively low and the irrigation channels are often of great length. Maintenence of irrigation channels and the building of new channels is a collective enterprise. (See Fig. 8.3.).

Fields represent previous river terraces and stones have to be removed when new fields are created. In the Samir valley the action of frost and snow brings down large amounts of scree which must be removed before ploughing. The clearing is done communally for late ploughing may endanger the harvest.

The plough is the basic agricultural implement of the area and differs little from that described by ROBERTSON (1898) in Nuristan. It is of timber construction with no mouldboard (Fig. 8.4.) only the share is of metal. Other implements such as the share and the sickle also require a minimum of metal.

Threshing is accomplished by bullocks harnessed together trampling on the wheat to separate the grain and the hay. The process is completed using a wooden winnowing fork.

A simple rotation is practiced with three main crops, where possible barley follows wheat and is followed by beans. The main effect of the rotation is to preserve the level of the soil nitrogen. As the proportions of the crops are unequal other devices such as mixing peas with grain crops are used to maintain nitrogen levels until the land is sown in beans. Most animal dung is used as fuel and manuring is restricted to the fields immediately around the village.

No reliable data could be obtained on crop yields though farmers estimate that yields of wheat from equal areas in the Samir and Panjshir fields may differ by five hundred percent. This fact has disturbing implications for a growth in the population would necessitate a highly disproportionate increase in the area of cultivated land and in the labour applied to it.

<u>The pastoral area.</u>

In such a harsh environment the people of Kaujan cannot survive entirely by cultivation, therefore they keep large numbers of sheep, goats and cattle. The village can hardly be considered an ideal location for a sedentary economy depending even partially on pastoralism. Though gradual snow melt provides soil water and gives rise to large areas of summer pastures there are no winter pastures. Pastoral activities are therefore limited by the amount of fodder collected during the summer.

Various plants are gathered for fodder, including at least two members of the Umbelliferae family, Ferula and Angelica. The fodder gathered in the mountains is then transported to the village on huge frames tied onto the back. (Fig. 8.5.).

Effective utilisation of the summer pastures relies on transhumance. As the snow retreats in spring the livestock are moved from the village to distant pastures in the Samir valley. Here two "Ailoqs" or shepherd huts at Sanjak and Khadangzor are occupied from mid June to late August. Similar systems of transhumance are found throughout south west Asia, but where amplitude of relief is greater the pattern is more complex. (BARTH 1956).

Shepherding is mainly the responsibility of the young people who at the same time collect fodder for the winter. Some milk is carried down to Kaujan in skins, more often however it is made into butter or cheese.

In total some 1,300 to 1,500 head of livestock belonging to the Tajiks are pastured in the Samir valley. Twenty percent are cattle mainly a small hardy strain with zube characteristics. The other eighty percent are split evenly between fat tailed, or Karakul sheep and hardy mountain goats. Over 1,000 animals can be wintered in the village whilst the rest are herded to Kabul in autumn to be sold.

Nomadic pastoralism is a much less demanding method of using the temporary summer pastures in the area, for the numbers of livestock are unrestricted by problems of fodder collection. The nomads can fully utilise the huge areas of summer pasture during their short period of productivity. They regularly graze sheep at altitudes above 12,000'. The nomad livestock are not as tolerant of cold as those of the Tajiks but are correspondingly more productive particularly of meat.

The products of pastoralism are the only source of cash income to both communities. Most important is the sale of wool, second is the sale of livestock. Dairy produce is exclusively for home consumption.

Supplementary Sectors of the Economy

Though agriculture and pastoralism provide a minimum for the diet, more primitive activities are employed to supplement it, these include fishing, hunting and gathering. The main prize of the hunter is the Ibex which provides both meat and hides. The Afghan hound is used in hunting though most of the villages own antiquated Indian Army rifles.

The gathering of natural produce is much more important than hunting of fishing. Wild rhubarb (Allium) is collected in large quantities for use as a vegetable and a wild onion (Rheum) is gathered from damp silt meadows even above 14,000' (Fig. 8.6.).

Though a monetary economy is well established exchange of produce is still common. The Tajiks trade wheat for the meat and butter of the Pathans.

The economy is not a true subsistence economy and livestock are regularly sent to Kabul to be sold at government controlled prices. Similarly the wool of the village is sold to buyers from Kabul. The meagre monetary income of the village is used to purchase necessary foodstuffs such as salt, sugar, and tea which cannot be grown locally. Metal agricultural implements are also bought, mainly in Charikar (40 miles down the Panjshir valley.) Access to the valley is sometimes difficult (Fig.8.7.).

The Farming Year

The year starts in spring when the farmers try to accelerate the melting of the snow by spreading dust on the fields. The triple process of ploughing, manuring and broadcasting the seed begins as the fields are cleared of snow. In the Samir valley ploughing may be delayed till June by slow snow melt, clearing of scree, and the laborious transport of the plough from one small field to another.

Regular weekly irrigation of the fields begins one month after sowing and continues until harvest. As the ploughing is nearing completion the nomad village and the shepherd huts are occupied. The ploughing completed, shearing begins and the uncleaned wool is ready for visiting buyers in late June. Fodder collection progresses throughout the summer and is intensified as winter approaches. As September begins the nomads leave for their winter pastures whilst the harvest begins in the fields in the Panjshir. In October the harvest from the higher fields is completed whilst the livestock which cannot be wintered are taken to Kabul for sale. By November the productive part of the year is over and the livestock are housed for the long winter.

Land Use in the Lower Panjshir Valley

Winter is not so prolonged in the lower Panjshir as in Kaujan. In Dasht-i-Revat at 7,500' snow rarely lies for more than two months. Spring arrives early and permits a greater variety of crops. More flat land is available and though population is greater, holdings are usually larger. The landscape is markedly different for tree crops including apricots, mulberries and walnuts can be successfully grown in Dasht. Wheat remains the main crop whilst corn takes second place from barley.

Pastoralism is still the only cource of monetary income but fodder collection is not such a constant concern as in Kaujan. The pattern of land use and life is still similar to that of Kaujan and there is still a delicate balance between population and potentially cultivable land.

Conclusions

In common with many other areas of the Hindu Kush the Kaujan region is characterised by a highly developed relationship between man and the land. The complex economy of the Tajiks depends mainly on a balance between subsistence cultivation and semi-commercial pastoralism though these are supplemented by more primitive activities which make productive even apparently barren areas. The Tajik village depends upon a very small area of irrigated, arable land which is delimited by micro-climate and more particularly by gradient. Subdivision of holdings prevents the most effective utilisation of the land but cannot be condemned under prevailing cultural conditions. Despite this qualification the utilisation of the land is still extremely effective. However under such limiting environmental conditions effective utilisation is incompatible with efficiency for, of necessity, the economy is highly labour intensive. Pastoralism is essential to the local economy but again is inefficient due to the problem of fodder collection.

The economy of the Pathans though different, displays an equally intimate interlinkage between man and his physical and biological environment. The Pathans rely on the Tajiks for grain but are otherwise economically dominant. Efficiency in pastoralism is achieved by movement of flocks thus avoiding the problem of fodder collection.

The two cultural groups are complementary rather than competitive and their separate existence assures the maximum use of land in the Kaujan region.

Certain disturbing implications must be noted. The survey reveals for example, a delicate balance between population and cultivable land. Any increase in population (such as could be rapidly brought about by modern medicine) could therefore only be offset by a more than proportional increase in the land area and the labour applied to it. As the land area is limited, the possibilities of increasing productivity by other means would seem to demand urgent attention. Neither the physical, nor the cultural background encourage mechanisation therefore the increasing of yields is a real priority. The eradication of bunt, the introduction of new crop strains, the use of fertilisers, all afford possibilities, but each would need financial aid. Resettlement schemes depending on the damming of river valleys and the irrigation of the plains, highlight the lack of basic data. Such schemes could only be implemented successfully after much needed investigations of the climate and hydrology. A detailed soil survey and a more thorough and widespread survey of the present patterns of land use with particular reference to the nomad population are also urgently required.

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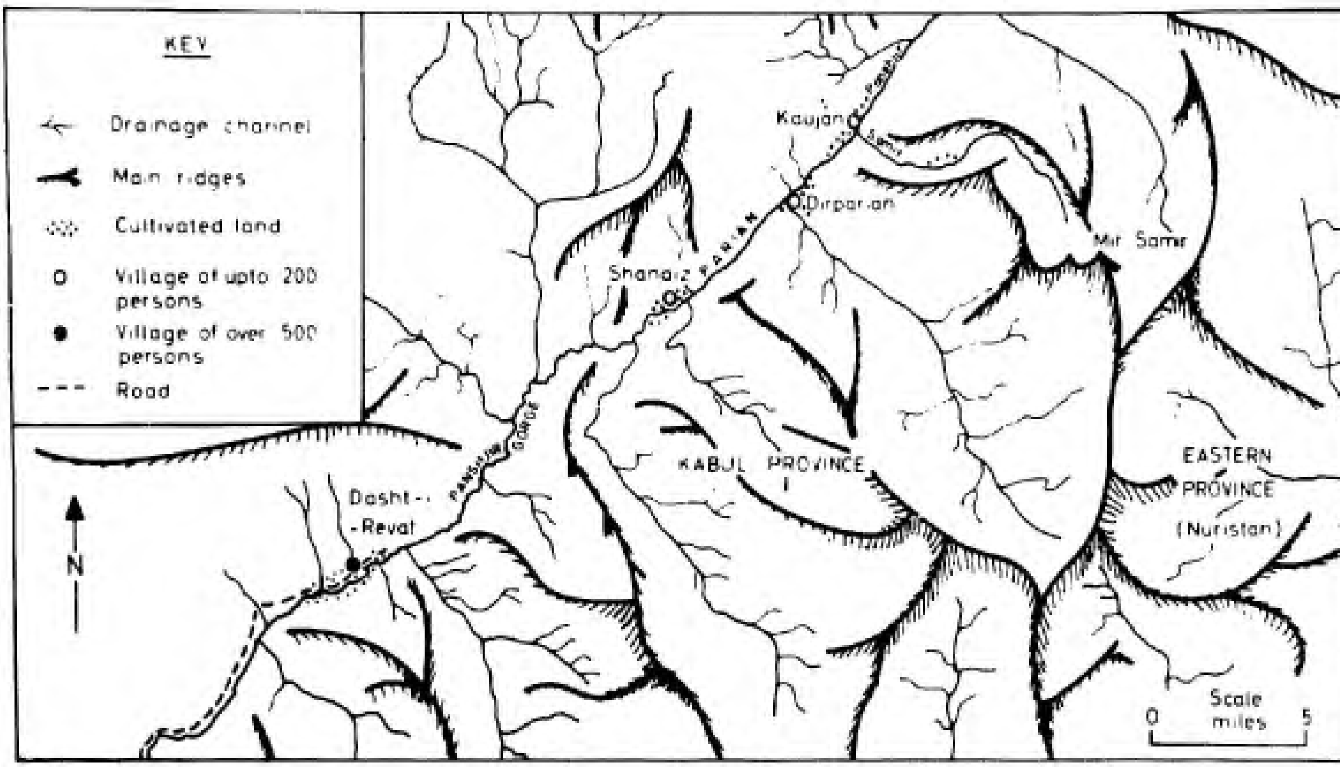

Fig.8.1. Map of Upper Panjshir Valley.

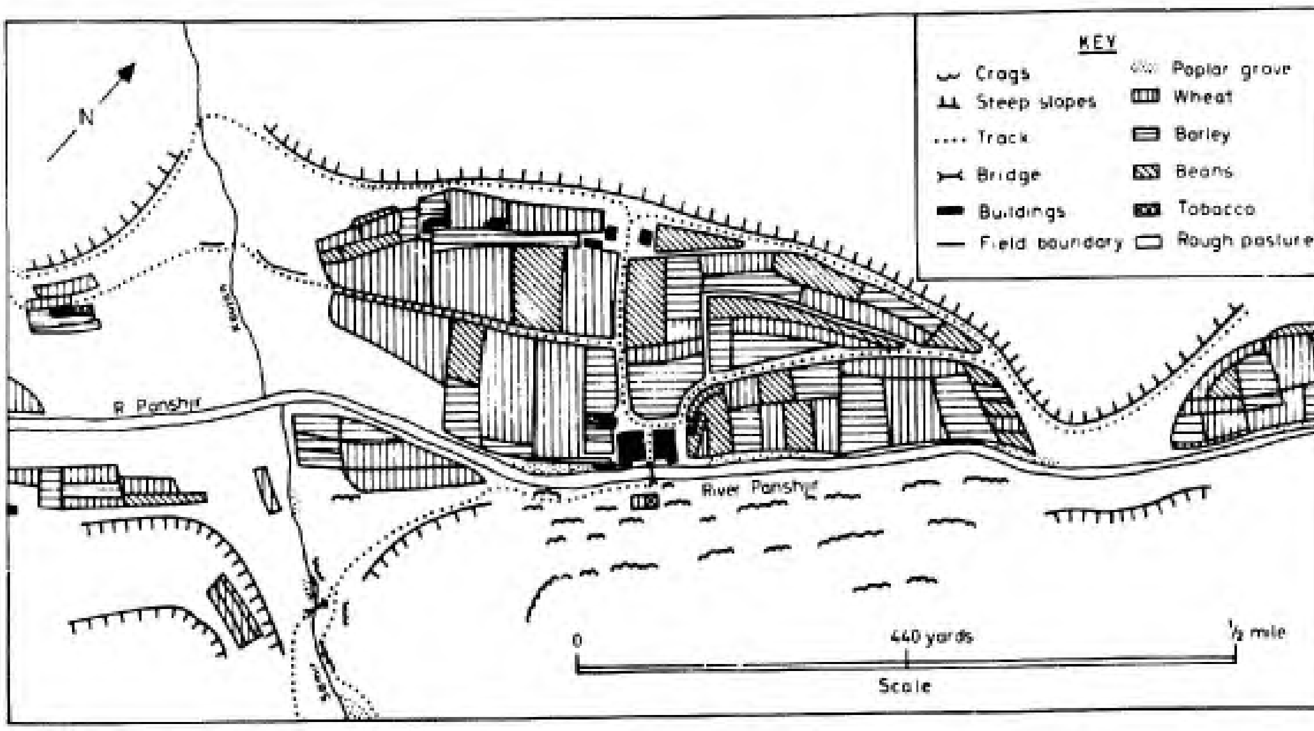

Fig.8.2. Land utilisation near Kanjan, 1965.

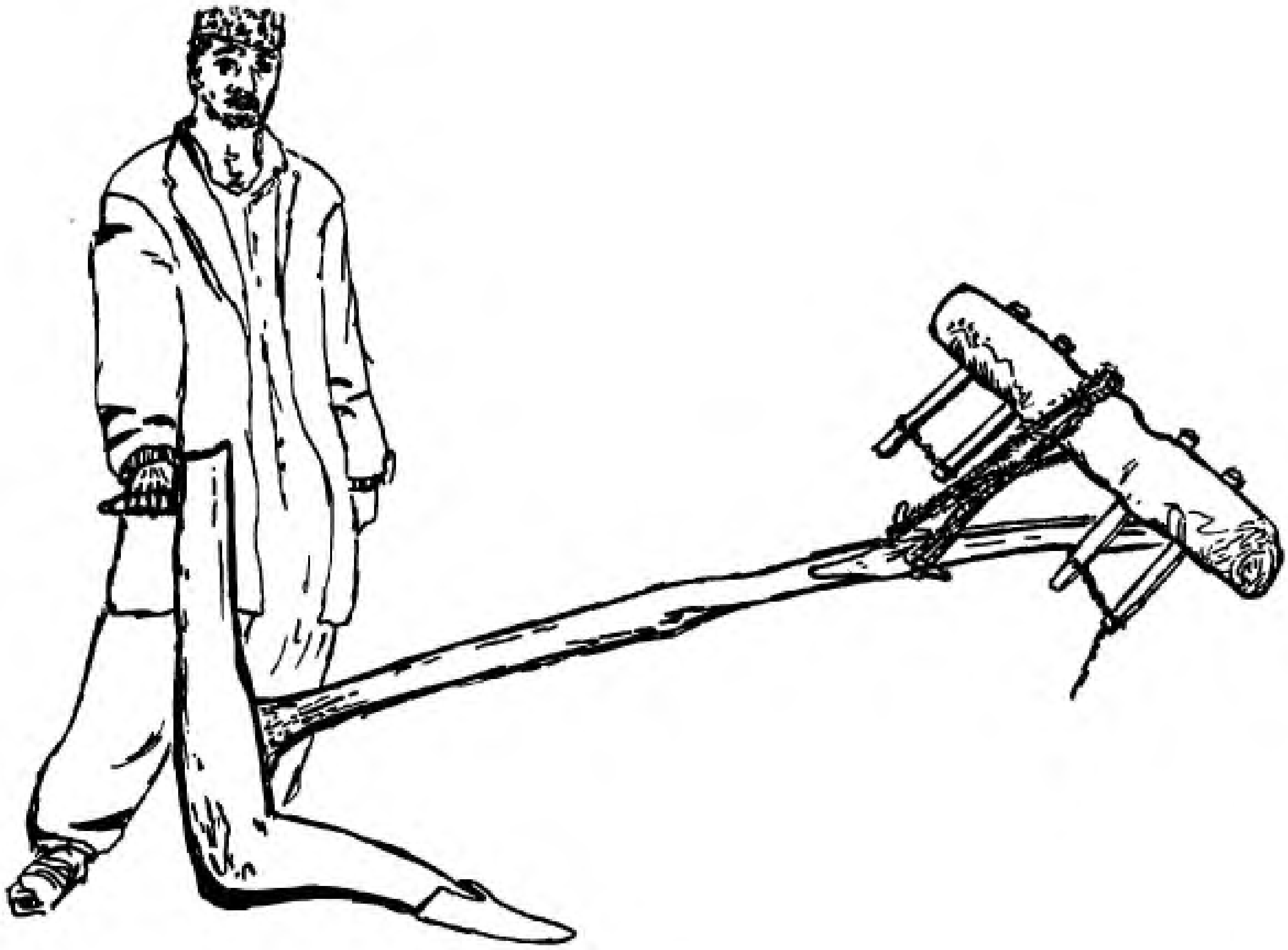

Fig.8.4. A Plough used in the Panjshir Valley. It is of primitive construction with no mouldboard and only the shape is metal.

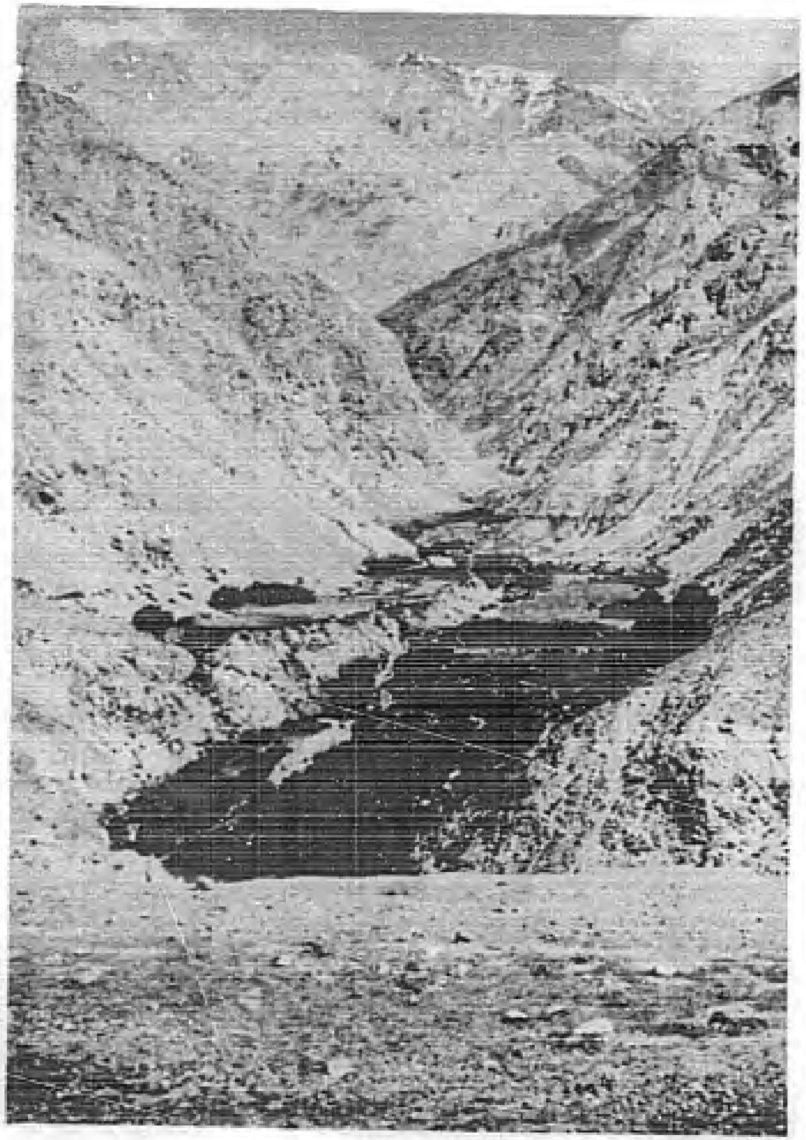

Fig.8.3. Arable land is produced by a combination of terracing and irrigation. Note the dark line of vegetation indicating the line of an irrigation ditch.

Fig.8.5. Umbelliferous and other plants are harvested from the steep hillsides and carried down to the village to be used as fodder or fuel.

Fig.8.6. Wild onions (Rheum) being gathered from high meadows (about 4500m).

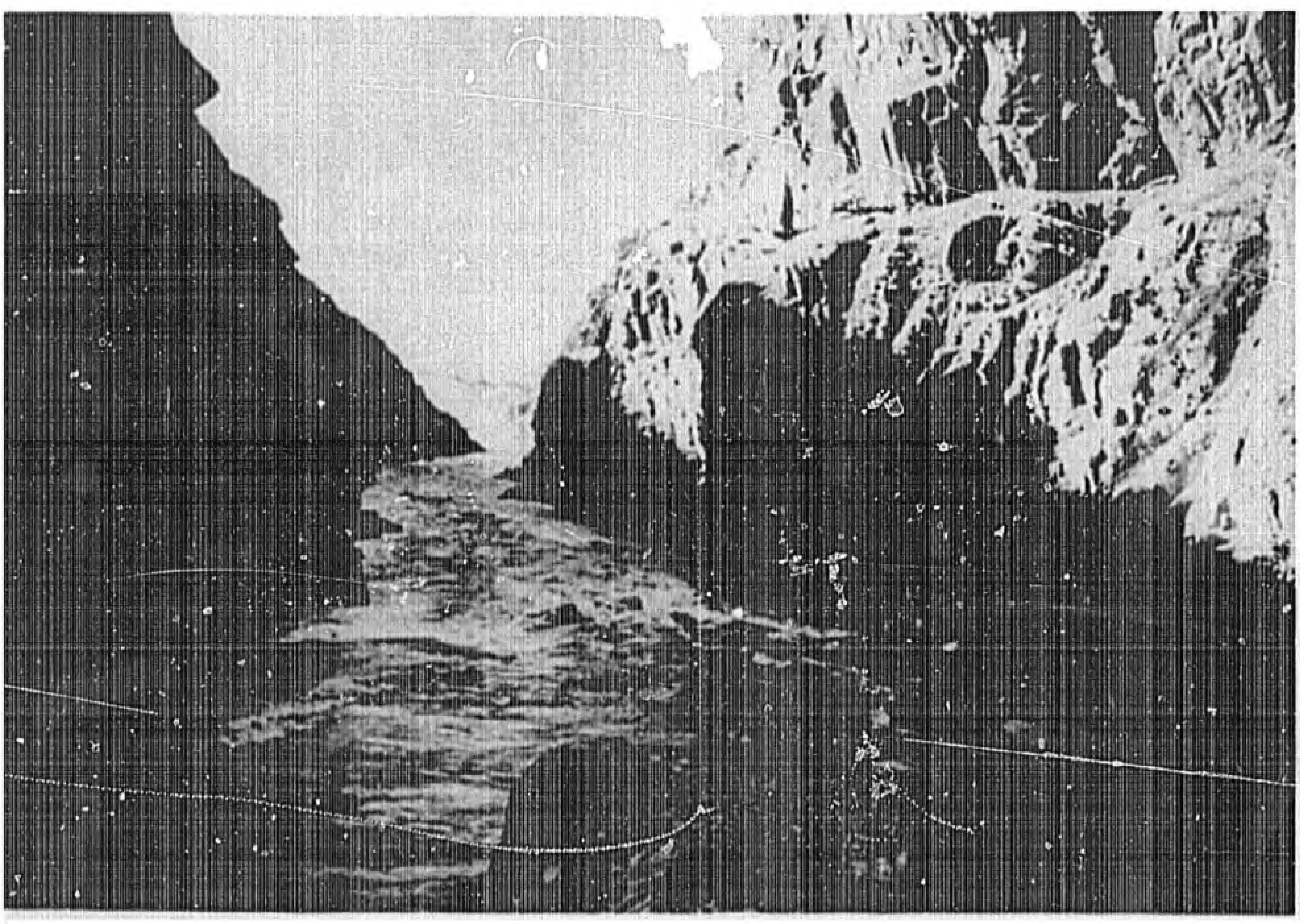

Fig.8.7. Access to the Panjshir Valley is from Charikar by this road blasted through a rocky gorge. The road is narrow and liable to flooding.

APPENDIX I

Medical Report

by J.P. Hurley

Preparation

The medical care of the expedition was handed over to me by Dr. John Payne of the University Health Service and I am grateful for his help in the early stages. On an expedition of this sort one had to try to prepare oneself for general illness, but with particular reference to tropical conditions, and possible injury to any of the members. One also had to cover the needs, if possible, of the people amongst whom we should stay. Due regard also had to be paid to weight and space.

The final list of drugs and instruments to be taken was formed from appendices of various mountaineering books, from help from Dr. Frederick Jackson and from the opportunely published 'Exploration Medicine' by Colonel Adams.

It seemed that with an expedition of this size the members could form a small blood transfusion service. Grouping revealed two A negative, one O negative, five A positive and four O positive. Two had had jaundice. Dr. Davis of the N.B.T.S. most helpfully organised this for us and provided transfusion sets and two pints of plasma.

Oxygen was not taken, nor thought necessary. The seriousness of respiratory illnesses at altitude was realised but one hoped not to meet high altitude pulmonary oedema.

No splints were taken. The recently introduced inflatable plastic type would have been ideal but were unfortunately expensive.

The drugs taken comprised samples from my practice and contributions from pharmaceutical firms approached by letter and through their representatives. These firms were extremely generous and nearly all gave what we asked and more at no cost, although one had been approached for other contributions to the expedition. One provided drugs at reduced price and asked for soil samples, which were obtained. The firms are acknowledge in Appendix IV.

Health of Expedition Members.

This was good. There were some upper respiratory infections, one combined with enteritis which caused some anxiety. There was also intermittent enteritis. Respiratory infections were treated with Rondomycin or Achromycin. Enteritis started at Tehran on the outward journey and ceased at Base Camp. On the return the pattern was reversed. This was probably due to eating local furit. The enteritis was treated with Tridia which was effective but bulky for transport, and with Streptotriad. These proved ineffective for the party in Pakistan, where Sulphaguanidine was helpful.

Acclimatisation

It seemed that observations on resting, heart rate and blood pressure at varying altitudes and the effect on them of acclimatisation were sparse, and Dr. L.G.C. Pugh of the Medical Research Council suggested that we might make such observations. This was done and the results passed to Dr. Pugh. One point of note was a transient hypertension lasting from one day in one case to four weeks in another, which disappeared on returning to lower altitudes.

Fluid intake and output measurements were abandoned. A diuresis did occur on reaching 7,000 feet. At 12,900 feet there was some urgent nocturia for about three weeks.

Headach, nausea, dizziness and shortness of breath occurred and was worse in those exerting themselves early. Cheyne-Stokes respiration occurred in some above 12,900 feet and cramp in one case at 15,400 feet. Mouth breathing and drooling were common. In general, acclimatisation took about a month, but two members were outstandingly fit.

Health of Local People

Here one suffered all the frustration of peripatetic medicine: lack of time, difficulty of communication, doubt of diagnosis and never seeing the result of treatment. There was a considerable amount of respiratory infection, some probable tuberculoses from glands of neck to terminal, a lobar pneumonia of thirteen days standing and various haemoptyses. There was much abdominal pain associated with stone meal grinding, worn teeth and dental abcesses. Impetigo and other skin diseases were common. Several children suffered from avitaminoses, being fed mainly on chapatties and having very little meat. There was much conjunctivitis, some corneal scarring and one foreign body of cornea.

Other illnesses included fibrositis, various wounds, varicose veins, osteoarthritis, anaenia, a carcinoma of colon, a possible appendicitis, stomatiti. an inguinal hernia, perforating ulcer of foot and various marasmic children.

Miscellaneous

Paludrine was used for malarial prophylaxis on the grounds that one tablet a day is more likely to be remembered than one or two a week. It was given from Austria onwards. There was no prophylaxis against amoebiasis. Phisohex was used by the cook who obtained a noteworthy freedom from enteritis during its use. Sunburn was averted by Uvistat which was effective to 16,000 feet. It was pleasant to use but tended to vanish with sweat. Sunburn, chiefly of lips but the worst was due to leaving off a wristwatch, was treated with cortisone ointments.

An epidemic of cholera of the El Tor variety caused some delay in return due to closing of frontiers and passage through various check points in Iran. Chloramphenicol was used in prophylaxis and May and Baker Ltd were helpful with information after our return.

Drugs used

Antibiotics

Rondomycin capsules	188
Achromycin capsules	115
Chloromycetin capsules	18
Penicillin G. tablets	143
Sulphatriad tablets	176
Tridia sachets	440
Streptotriad tablets	148
Sulphasuccidine tablets	190
Penitriad tablets	30
Midicel tablets	12
Bidizole tablets	40
Ganatol tablets	80

Antacids

Alcin tablets	230
Droxalin tablets	146
Gastrils	48

Sedatives

Soneryl tablets	6

Suppositories

Proctosedyl	6

Ointments

Cortisone +/- neomycin tubes	12
spray	2

Purgatives

Senokot tablets	24

Iron

tablets	50

Vitamins

Multivite tablets	500
Various	80

Anaesthetic

ointment	1

Antimalarial

Paludrine tablets	1,500

Analgesics

Codis tablets	420
Disprin tablets	425
Paynocil tablets	36
DF 118 tablets	24

Eye drops and ointment

Various	24

Sunburn

Uvistat tubes	12

Rukefacient

Anabalm tubes	6

Insects

Waspeze	8
Mylol tubes	15
Insecticide	2

Antiseptics

Dettol cream	1
Phisohex	2

Anthelmuritics

Pripsen	2
Antipar tablets	26

Gauze 1 pkt.

Cotton wool 1 pkt.

Bandages 4 x 3"

A considerable amount of drugs remaining on our return was given to the Flora of Turkey Expedition 1966.

Acknowledgements

In preparation and the matter of tropical illnesses and prophylaxis I am grateful for the help of Sir Arthur Porritt, Professor Morgan, Professor A.W. Woodruff and other colleagues and friends.

Finally, my thanks must go to my locum Dr. Odling-Smee and above all to my partners Dr. Millar and Dr. Cosgrave who let me leave the practice for three months for a most interesting and rewarding experience.

DENTAL REPORT

by A. D. G. Beynon

Dental Treatment

The detail health of the expedition members was generally good. One permanent filling was lost and a temporary filling was inserted.

In the case of the indigenous population the only practical treatment for the relief of dental pain and sepsis was tooth extraction, as follow-up treatment was not possible. All extractions were performed under local anaesthetic, a luxury apparently unknown and widely appreciated once the fear of the treatment had been overcome. Altogether 200 extractions were carried out during the journey up the Panjshir Valley and on itinerant patients at base camp.

Wherever possible instruments were boiled but circumstances frequently rendered this impossible. Instruments were stored in Savlon after boiling and used directly. The resistance of the local people was apparently sufficient to resist the inherent dangers in this procedure.

Equipment and Materials

The following equipment and materials were used:

(a)	Forceps	-	2 upper root (fine and heavy)
		-	2 lower root (fine and heavy)
		-	1 upper straight
		-	1 bayonet upper
		-	1 lower cowhorn
		-	2 pairs Spencer Wells
(b)	2 Sterilling cartridge syringes		
(c)	Elevators	-	1 straight
		-	Warwick-James (left and right)
(d)	Mirrors and Probes		
(e)	Drugs	-	1 litre Savlon
		-	4 packs of 60 cartridges of 2% Xylocame (1:80,000 adrenalin).
		-	2 packs of quick setting zinc oxide/Eugenol paste.

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APPENDIX II

Travel Report

by A. James & J. Hubbick

The scientific programme described in this Report entailed the transport of 12 people, food for 1000 man-days and approximately 2 tons of climbing, camping and scientific equipment from Newcastle upon Tyne to the Samir Valley and back again. The aim in making the travel arrangements was to strike a balance between the conflicting claims of expense and efficient utilization of time. When the arrangements were being made the party consisted of 15 people and it was decided to divide this into 2 groups of 7 plus the Leader. Group I would drive out in two vehicles, a Land Rover station wagon and an ex-Army 4 x 4 Humber truck, with the Leader. Group II would fly out and on the return journey the driving and flying roles would be reversed except that the Leader would once again accompany the ground party. This would enable the whole party to spend eight weeks on site for a total absence of 12 weeks. (4 weeks for surface journey), whilst minimising the cost of air fares. At the last moment three members were unable to take part in the expedition and this factor, together with cholera outbreak and the delayed departure of Group II, caused some modification to be made to the original programme. The detailed working of the revised arrangements, together with a road report, are described below.

Diary of Events

8 June	Group I (A. James, M. James, J. Hubbick, D. Beynon, O. Gilbert, H. Horsley, M. Earle and D. Jamieson) left Newcastle upon Tyne and drove to London.
9 June	After collecting Afghan visas, insurance certificates and some supplies the Group left England on the midnight ferry.
10 June	Ostend to Cologne (190 miles). Rearranged packing of vehicles.
11 June	Cologne to Munich (360 miles). Autobahn all the way.
12 June	Munich to Graz (290 miles). Autobahn to Salzburg. Narrow winding road afterwards. Road being reconstructed after flooding.
13 June	Graz to Slavonski (280 miles). From Yugoslav border to Zagreb diversion due to flooding. Autoput surface rough in places but generally fair.
14 June	Slavonski to Sofia (200 Miles). Autoput to Nis and then good road to Bulgarian border. Cobbled road thereafter, narrow and with much slow-moving traffic.

15 June	Sofia to Edirne (220miles). Cobbled road with some better stretches of asphalt.
16 June	Edirne to Istanbul (170 miles). Mainly good tarmac but some potholes. Reorganized packing of truck and Land Rover. Vehicles serviced.
17 June	Istanbul to Ankara (290 miles). Good tarmac all the way except for 10 miles of cobbles.
18 June	Ankara to Samsun (266 miles). 30 miles of good tarmac, the remainder rough and unsurfaced. Extensive road works. Puncture on lorry due to rapid wear on front tyres.
19 June	Samsun to Trabzon (280 miles). Surfaced to Ordu but afterwards unsurfaced, bumpy with narrow mountainous section. Delay in Trabzon due to purchase and fitting of new tyre.
20 June	Trabzon to Bayburt (130 miles). Dirt road but smooth surface and well-graded 6,500 t pass. Stopped early because of puncture in rear tyre of truck.
21 June	Bayburt to Maku (330 miles). A mixture of good dirt roads and potholed tarmac. Crossed two passes over 8,000 ft. Delayed at Turkish-Iranian border.
22 June	Maku to Siah Chaman (250 miles). Very poor corrugated road. Extensive road works. Some good new tarmac near Tabriz.
23 June	Siah Chaman to Banas (250 miles). Mainly poor corrugated road with no surface. Long delay in morning due to puncture in front tyre of truck.
24 June	Banas to Tehran (150 miles). Poor road to Takistan, thereafter good tarmac.
25 June	Tehran. Reorganization of vehicles.
26 June	Tehran - Abgarm (70 miles). Lats start after vehicles serviced. New tyre fitted on truck. Excellent road through Elburtz mountains.
27 June	Abgarm - Bojnoord (300 miles). Good surfaced road to Gorgan, afterwards good gravel road with some roadworks.
28 June	Bojnoord - Meshed (200 miles). Fair gravel road. Slow progress beacuse of tyre trouble.

29 June	Meshed - Islam Quala (200 miles). Good gravel road near Meshed, then surfaced for 50 miles but remainder to Afghan border very poor. Start delayed by fitting tyre on truck.
30 June	Islam Quala to Shindand (250 miles). Poor dirt road to Herat but from then on excellent fast tarmac road.
1 July	Shindand to near Makur (280 miles). First-class road but forced to stop 180 miles before Kabul due to fatigue in rear wheel studs on truck.
2 July	Makur (10 miles). A tightening of wheel studs by shims proved unsuccessful. Most of the day spent in dismantling rear hub on truck. P. Hurley left England by air for Kabul.
3 July	Makur - Kabul (170 miles). Land Rover only. D. Beynon & J. Hubbick left behind with truck. 120 miles corrugated gravel road, thereafter serviced. Arrangements made for replacement of wheel studs. Party met by P. Hurley.
4 July) 5 July)	Completed formalities with Afghan authorities.
6 July	A. James & D. Jamieson collected new studs and returned to Makur. Remainder of party completed arrangements for liaison officer and collected local supplies.
7 July	Land Rover and Humber returned to Kabul. All the party plus Mohammad John (liaison officer) drove up the Panjshir Valley.
8 July	Drove to Sangahnar (14 miles) where road was washed away. Transferred stores etc. by mule to bus at far side of flood.
9 July	A. James and J. Hubbick returned to Kabul in Land Rover, and Humber. The remainder of the party went by bus to Dasht-i-Rewat, where arrangements were made for horses. H. Lister, A. Pendlington and J. Parry left England by air.
10 July	Forward party had late start due to horsemen - 8 miles up Panjshir Valley. A. James & J. Hubbick repaired puncture in tyre on truck and met the remainder of Group II at the airport.
11 July	Forward party arrived in Kaujan (12 miles). Formalities for Group II completed with Afghan authorities. Afterwards drove up to Panjshir Valley.

12 July	Forward party established camp on Lower Meadow. Second party went by Land Rover to Sangahnar and by bus to Dasht-i-Rewat.
13 July	Forward party reconnoitred Upper Samir Valley. Second party had late start due to horsemen and then walked 15 miles up Panjshir Valley.
14 July	Forward Party completed sketch map of Upper Samir Valley. Second party walked up Samir Valley to near Lower Meadow.
15 July	Both parties combined to establish Base Camp on Higher Meadow.

16 July to 24 August. Scientific programme carried out. In this period J. Parry and M. Earle spent 17 days carrying out a geophysical and geomorphological study in Pakistan.

26 August	Whole party returned to Kabul.
30 August	M. James & J. Hubbick flew back to England.
3 September	D. Beynon, D. Jamieson, H. Horsley, M. Earle & O. Gilbert flew back to England.
6 September	Remainder of party set off for return journey in Land Rover and Humber. The return had been delayed due to a cholera outbreak and this caused subsequent delays in Iran. The same route was followed.
16 September	A. James left return party at Trabzon and flew back to England.
29 September	Ground party arrived in Newcastle.

During the return journey a half-shaft snapped on the offside rear wheel of the truck. This, and the other difficulties experienced with the truck (wheel studs and excessive tyre wear), were due to overloading. When the amount of material transported by the Humber truck is taken into consideration it emerges as an excellent vehicle for this type of undertaking. Only a few minor faults were experienced with the Land Rover.

The outbreak of Cholera prevented us from taking advantage of the cheap Kabul-London airfares via Moscow.

APPENDIX III

Food Report

by M. James

Supplies were required for approximately 1,000 man days - made up as follows:

Outward Journey	8 men for 25 days
Base or in the field	12 men for 60 days
Return journey	4 men for 20 days

Extra persons increased the numbers at base and on the outward journey for part of the time, but this is cancelled out by the fact that several hotel and restaurant meals were taken in Tehran and Kabul.

Food consumed

200 lbs dried meat (small amount rice or instant potato included)

84 lbs tinned meat (journey only)

96 two-man freeze-dried meals (base camp only - vegetables and rice or pasta included)

20 lbs dried vegetables (peas, beans, lentils)

15 lbs freeze-dried peas and beans

20 lbs extra instant potato

20 lbs extra rice

30 lbs macaroni

40 lbs dehydrated soup

170 lbs porage oats

30 lbs Grapenuts

200 lbs Vita-Weat crispbread

70 lbs dried milk powder

270 lbs sugar

20 lbs tea

18 lbs instant coffee

100 lbs processed cheese

100 lbs digestive biscuits

70 lbs tinned margarine

48	lbs fruit cake
100	lbs jam
40	lbs golden syrup
40	lbs boiled sweets
10	lbs chocolate
30	lbs sultanas
7	lbs prunes
20	lbs cocoa
8	lbs Horlicks
8	lbs Ovaltine
20	lbs salt
30	lbs chutney and sauce

Assorted spices and herbs.

These stores provided a varied and satisfying diet and the food was quick to prepare and easy to cook on Primus stoves, despite the high altitude. There are, however, two improvements which could have been made:

Most of us became rather tired of eating the same crispbread all the time and it would have been better to take half of the amount in ships' biscuits plus another type of crispbread to avoid monotony.

As the weather became colder towards the end of the period at base camp fried food was in great demand. A small amount of cooking oil would have been useful because the margarine, excellent in other respects, was not very satisfactory for frying.

APPENDIX IV

Acknowledgements

We wish to express our thanks to the Senate and Council of the University of Newcastle upon Tyne for sponsoring the expedition and for granting leave of absence to members of staff to take part. In particular we would like to thank the Vice-Chancellor, Dr. C.I.C. Bosanquet, and the retired Deputy Vice-Chancellor, Professor G.H.J. Daysh, for their help and encouragement. We should also like to thank the Head of the Photography Department, Mr. C.J. Duncan, and Mr. Ridley and Miss Watts for help with still and cine photography.

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APPENDIX V

Expedition Accounts

Income

	£
Personal Contributions	1,950
University of Newcastle upon Tyne	600
United States Army, European Research Office	2,000
Mount Everest Foundation	750
Royal Geographical Society	200
Sir Frank Schon, Marchon Products Ltd.	100
Commercial Plastics	100
C.A. Parsons & Co. Ltd.	50
Mr. J.B. Morton, Stanley Miller Ltd.	50
Northern Gas Board	25
I.C.I. (Petrol vouchers)	25
Mr. H.S. Thorne, Thorne's Students' Bookshop	20
Storey Sons and Parker	10
Television appearances	25
TOTAL	5,905

Expenditure

	£
Air Transport	1,400
Land Transport	1,900
Local Transport(Porters, Horses etc.)	245
Equipment (camping)	440
Equipment (Scientific)	350
Insurance	200
Food	650
Interest charges	150
Hotels	150
Technical assistance	120
Organization	120
Expedition Report	180
TOTAL	5,905

After the Expedition returned to Newcastle the camping equipment and surplus food were donated to the University Exploration Society.

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13. ABSTRACT

The report presents the results of an expedition to make meteorological and hydrological observations on a tropical glacier. Ancillary studies were made of other environmental features and were to be combined with an examination of the plant, animal and human communities to give an integrated picture of the region. The report covers the Glaciology, Meteorology, Hydrology, Geomorphology, Limnology, Botany, Dental Anthropology, and Land Use. ( )

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Dental Anthropology						
Land Use						