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ANALOGS OF YUMA TERRAIN IN THE NORTHWEST AFRICAN DESERT

TECHNICAL REPORT NO. 3-630

Report 6

Volume II

[redacted]

JUNE 1965

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

- LIST OF PLATES -

SECTION I:
BASIC TERRAIN FACTOR AND ANALOG MAPS

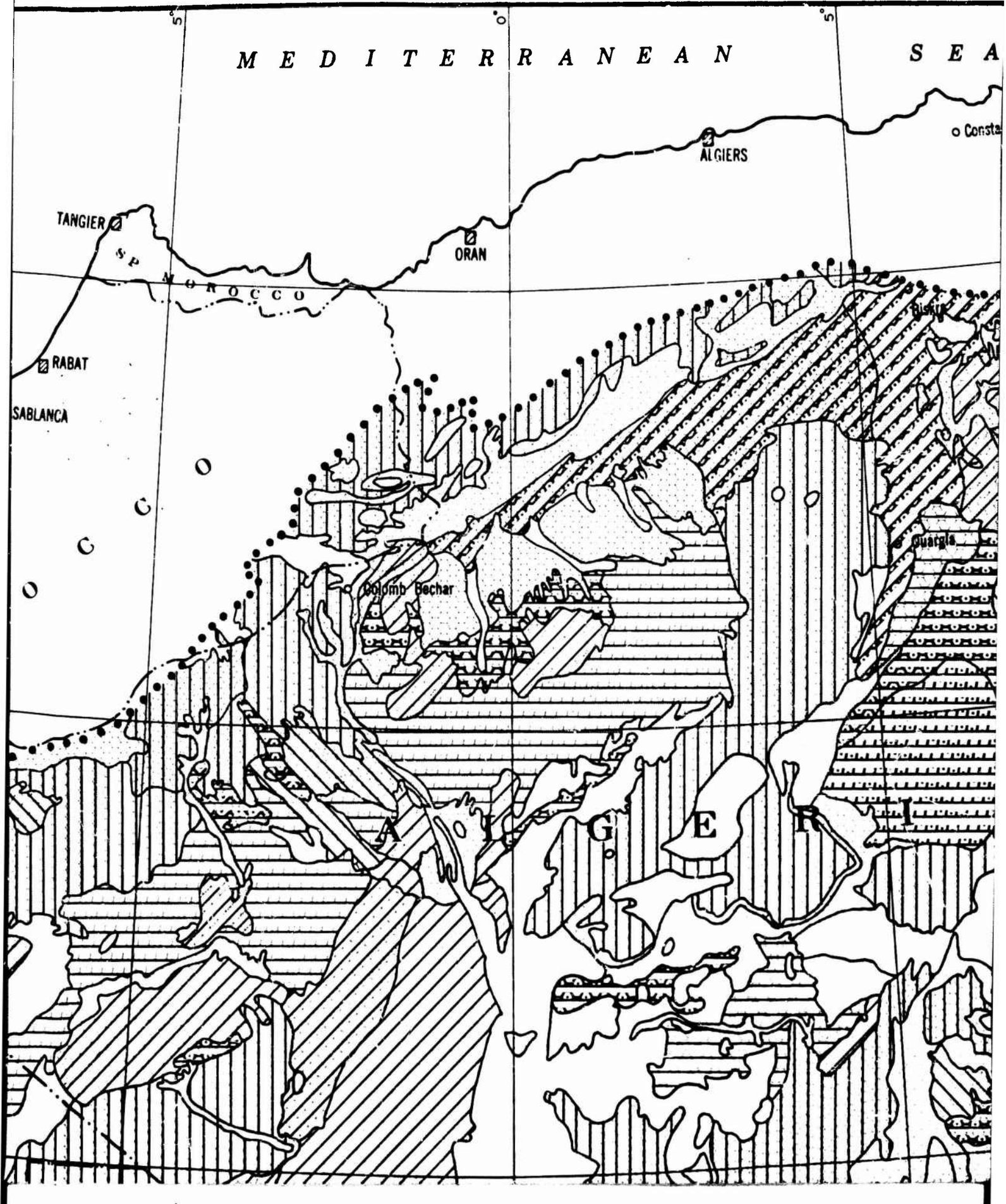
SECTION II:
SUPPLEMENTAL MAPS AND TABULATIONS

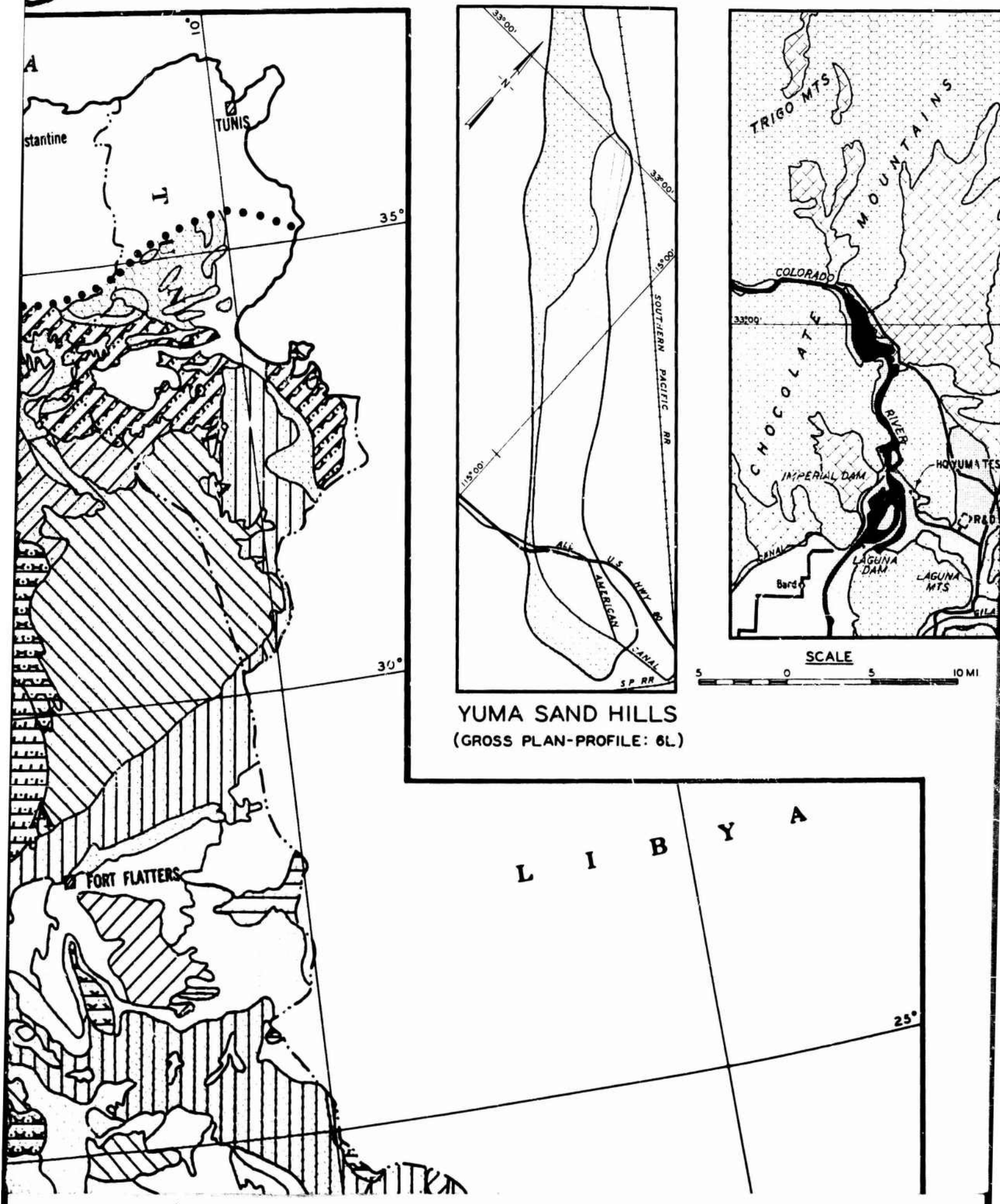
SECTION II:
SUPPLEMENTAL MAPS AND TABULATIONS

ANALOGS OF YUMA TERRAIN IN THE NORTHWEST AFRICAN DESERT

SECTION I: BASIC TERRAIN FACTOR AND ANALOG MAPS

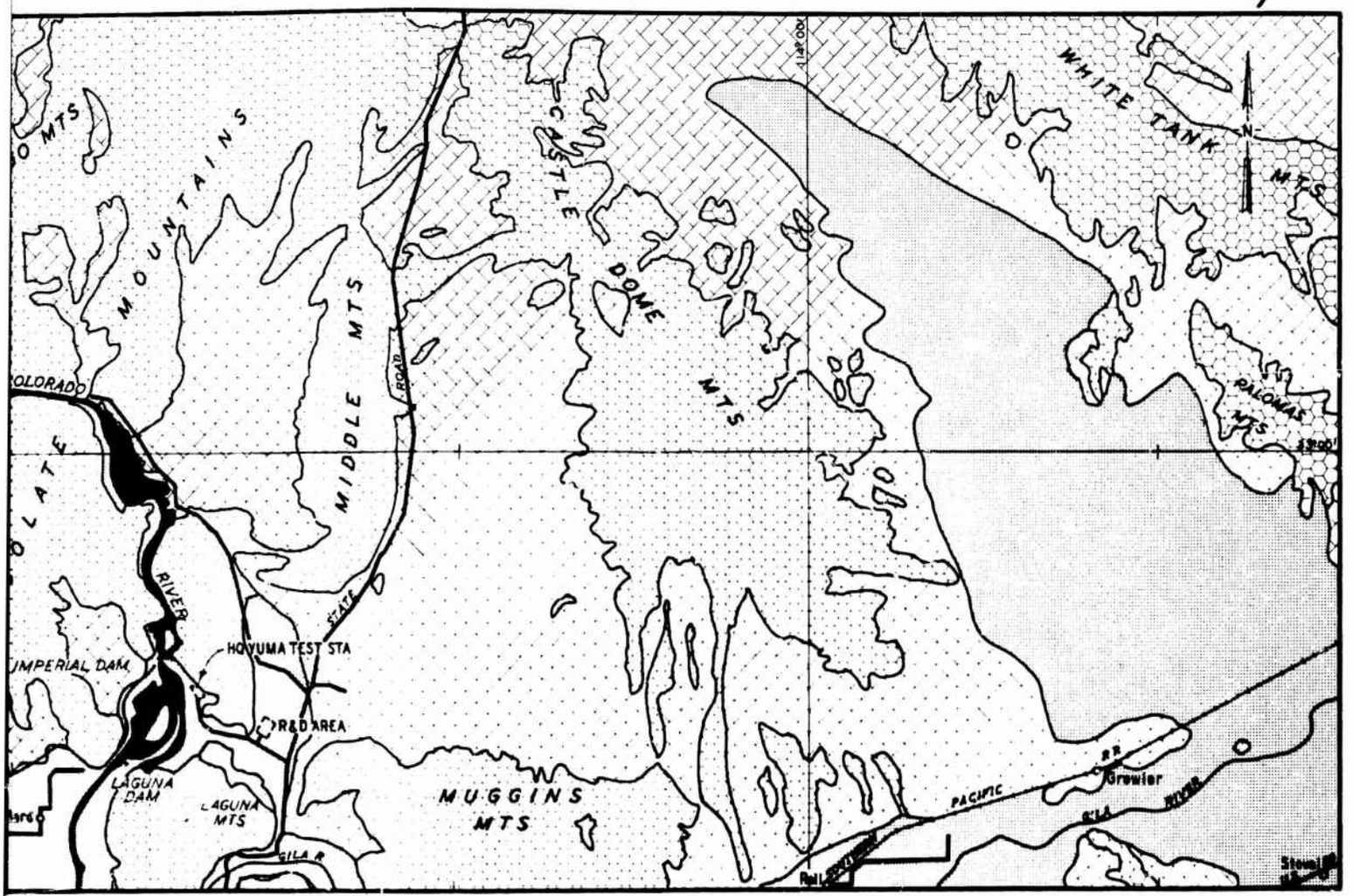

20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
CASABLAN
MARRAKECH
Mogador
M O R O
IFNI
SAHARA
SAHARA
VILLA CISNEROS


MEDITERRANEAN SEA
ALGIERS
TANGIER
ORAN
SP. MOROCCO
RABAT
SABLANCA
Colomb Bechar
Ouargla
ALGERIA



YUMA SAND HILLS

(GROSS PLAN-PROFILE: 6L)



YUMA TEST STATION

(GROSS PLAN-PROFILE: 5L//)

A

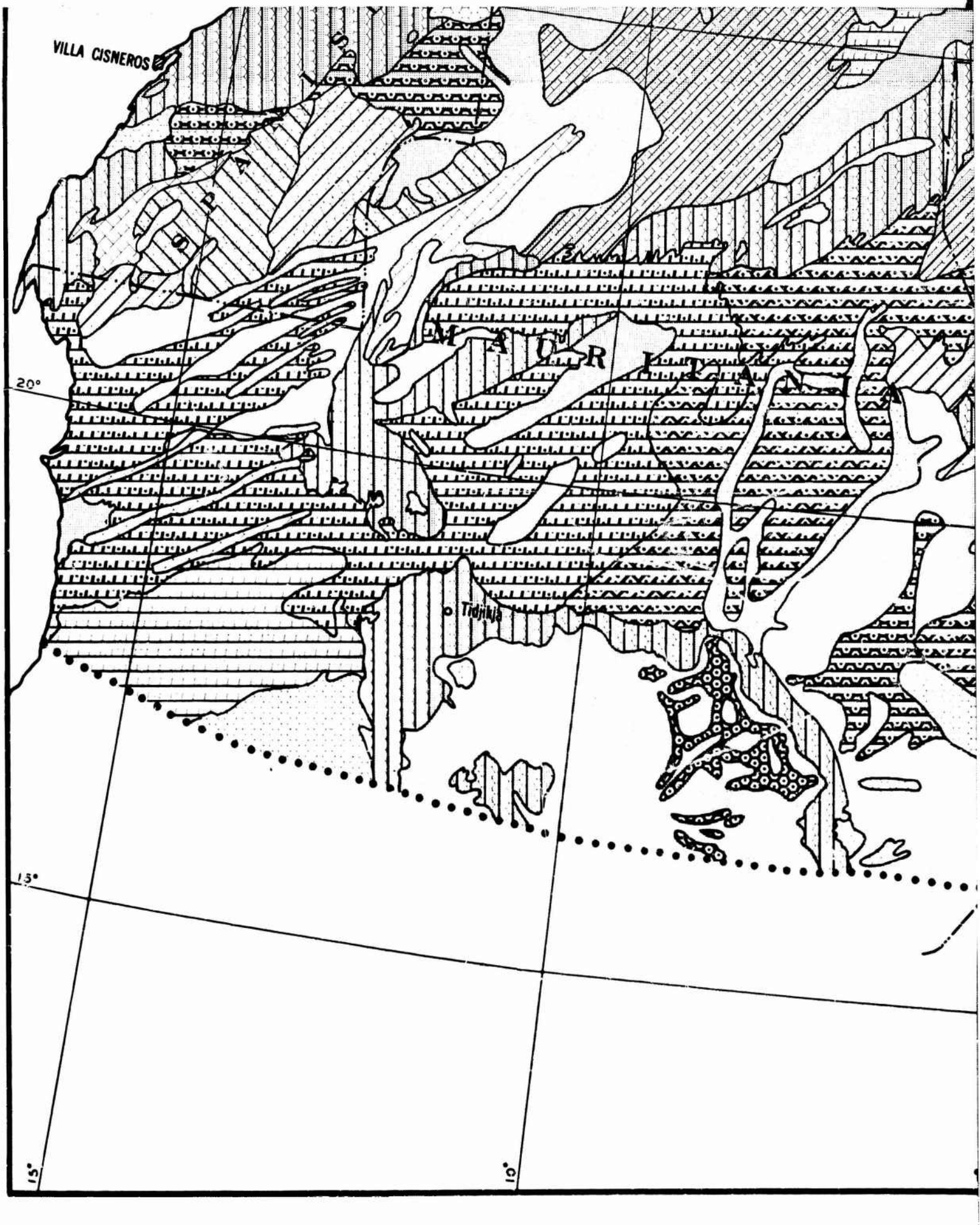
25°

CHARACTERISTIC PLAN-PROFILE

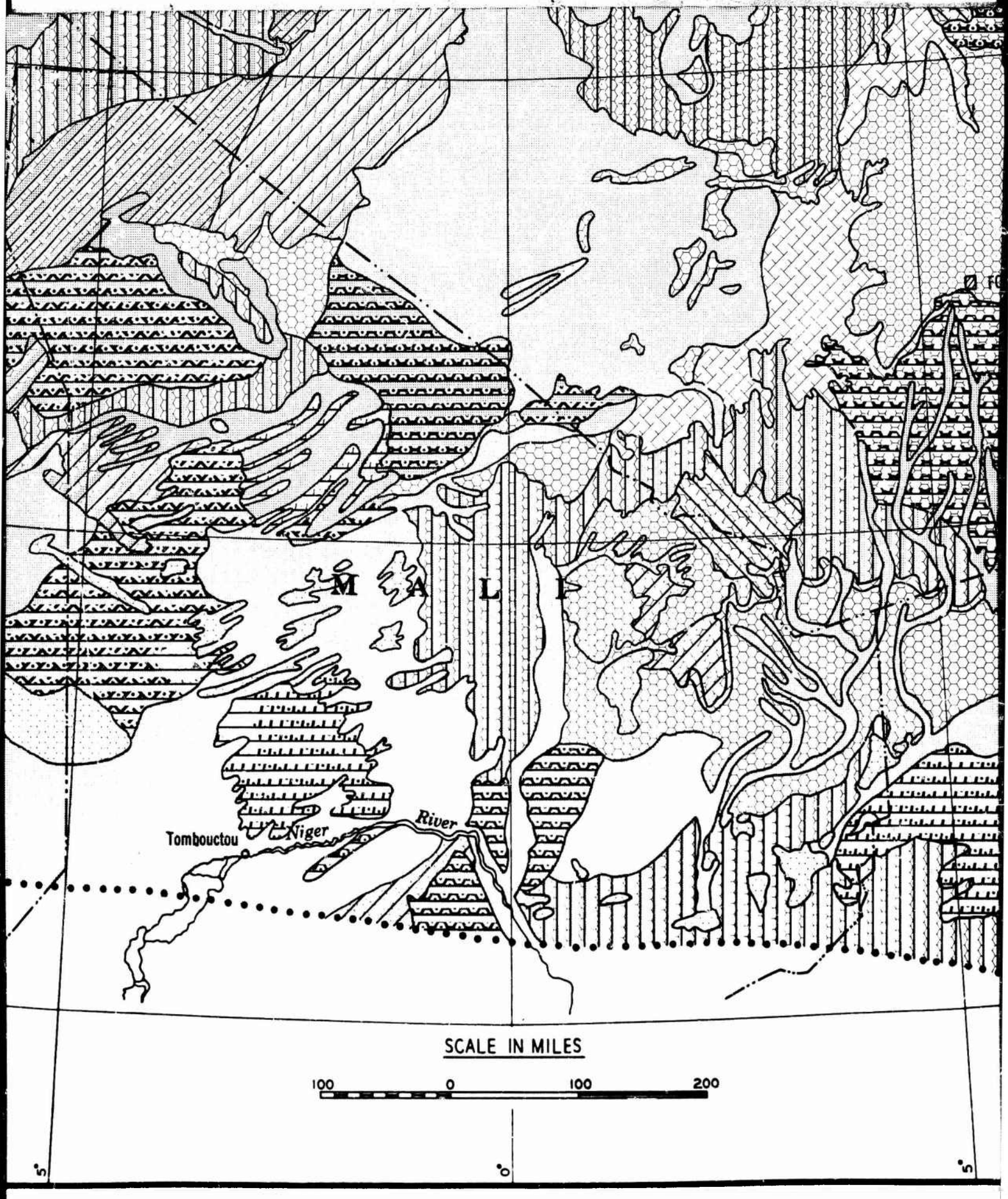
The characteristic plan-profile is the most commonly found plan-profile within a region. It may be either restrictive or gross. The restrictive plan-profile is based on random sampling with circles 1 mile in diameter. Local relief of less than 10 ft is not considered. The gross plan-profile is based on random sampling with circles 55 miles in diameter. Relief of less than 100 ft is not considered. The prominences in such a plan-profile are termed component highs, the intervening lowlands component lows.

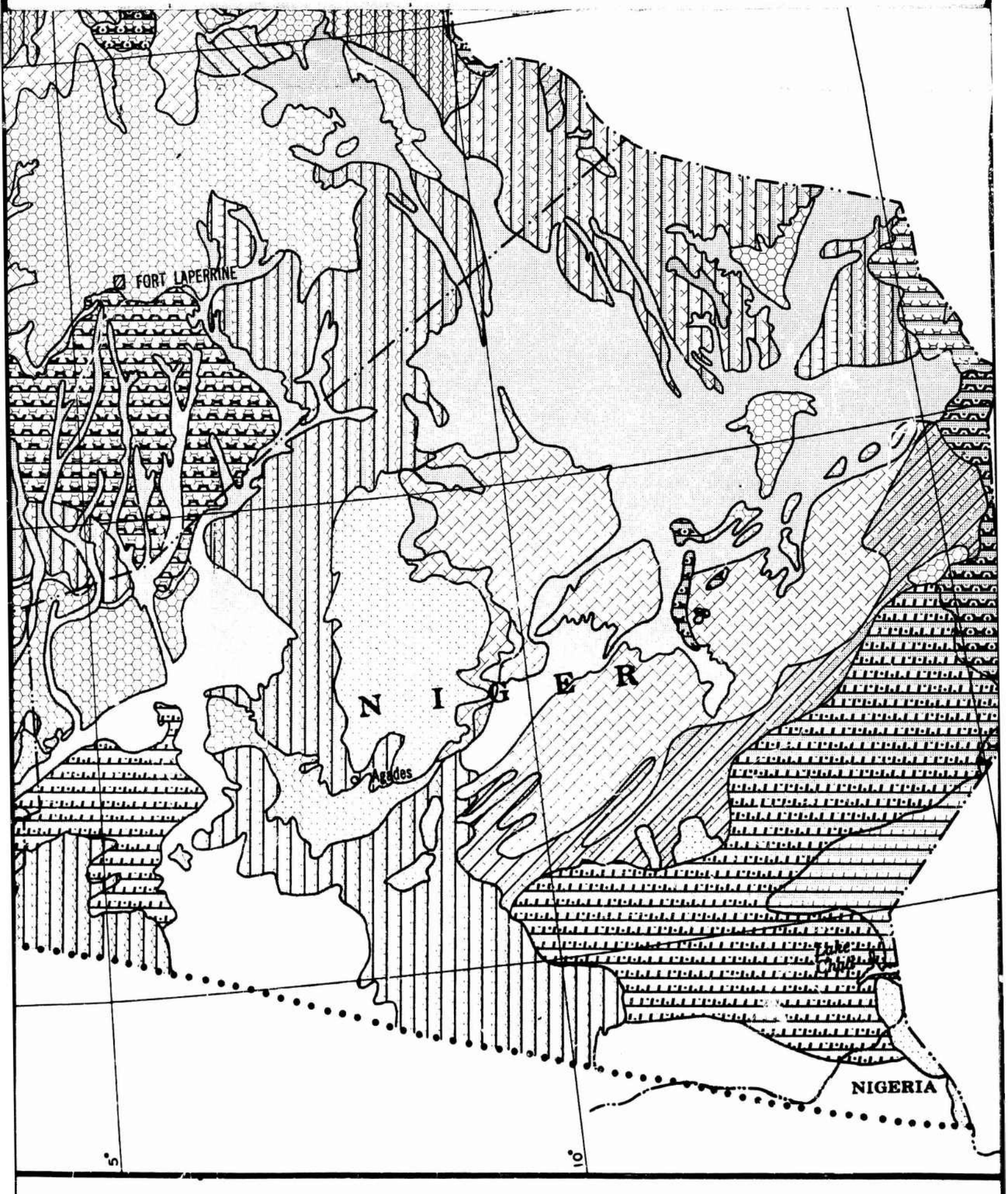
LEGEND

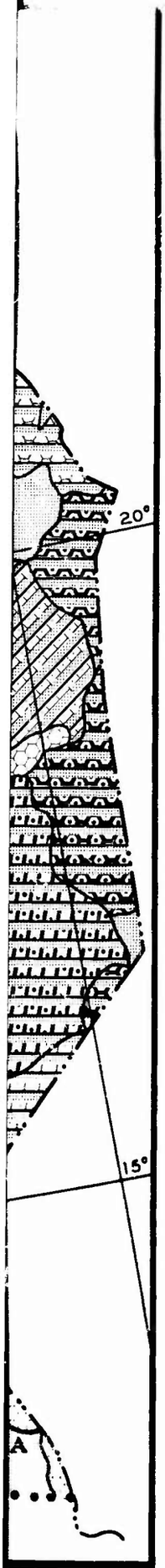
Highs Occupy:	Highs are → Schematic Plan / Schematic Profile	Nonlinear and Random	Linear and Random	Nonlinear and Parallel	Linear and Parallel
>60% of area	Flat-topped	1	1L	1//	1L//
40-60% of area	Flat-topped	2	2L	2//	2L//
<40% of area	Flat-topped	3	3L	3//	3L//



5


M A L I
Tombouctou
Niger River
SCALE IN MILES
100 0 100 200
5°
0°
5°


FORT LAPERRINE
N I G E R
Agadez
Lake Chad
NIGERIA
5°
10°



	Flat					
<40% of area			3	3L	3//	3L//
>60% of area	Crested or Peaked		4	4L	4//	4L//
40-60% of area			5	5L	5//	5L//
<40% of area			6	6L	6//	6L//
No pronounced highs or lows			7			

PLAN-PROFILE COMPLEXES:

Areal Complexes: Confined to areas where two major, areally restricted plan-profiles, both of the restrictive type, are mapped.

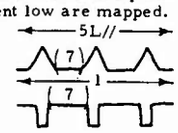
1 / 4 — Plan-profile of the areally predominant lows.
Plan-profile of the areally subordinate highs.

1 \ 4 — Plan-profile of the areally predominant highs.
Plan-profile of the areally subordinate lows.

Gross-component Complexes: Confined to areas where a gross and a restrictive plan-profile of either a component high or a component low are mapped.

5L// / 7 — Gross plan-profile.
Restrictive plan-profile of component lows.

1 | 7 — Gross plan-profile.
Restrictive plan-profile of component highs.



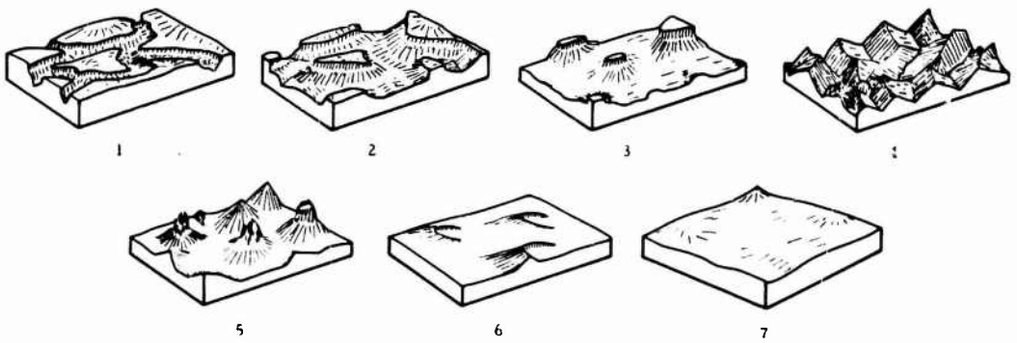
* Highs are considered to be (1) peaked or crested prominences which exhibit characteristic slopes greater than 6 degrees or (2) fairly flat-topped prominences or high-level areas bounded by slopes in excess of 14 degrees.

** L indicates linearity of highs. A high is considered to be linear when its length is greater than 5 times its width.

*** // indicates roughly parallel arrangement of highs or aligned highs.

REPRESENTATIVE PLAN-PROFILES

Each of the following block diagrams illustrates a landscape representative of a specific plan-profile type. It should be emphasized that, within the defined limits of each type, a wide variety of landscape configurations are possible.

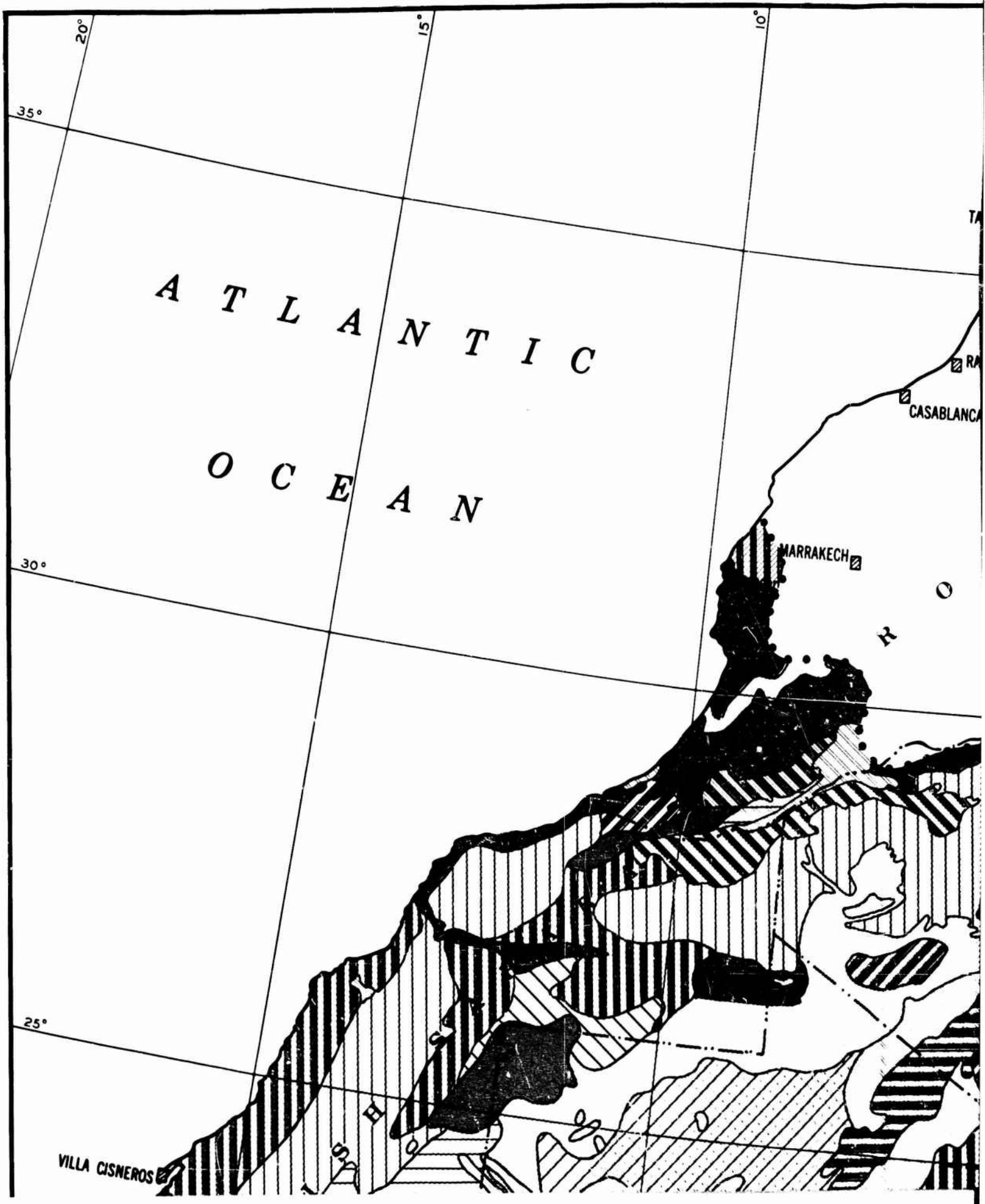


ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

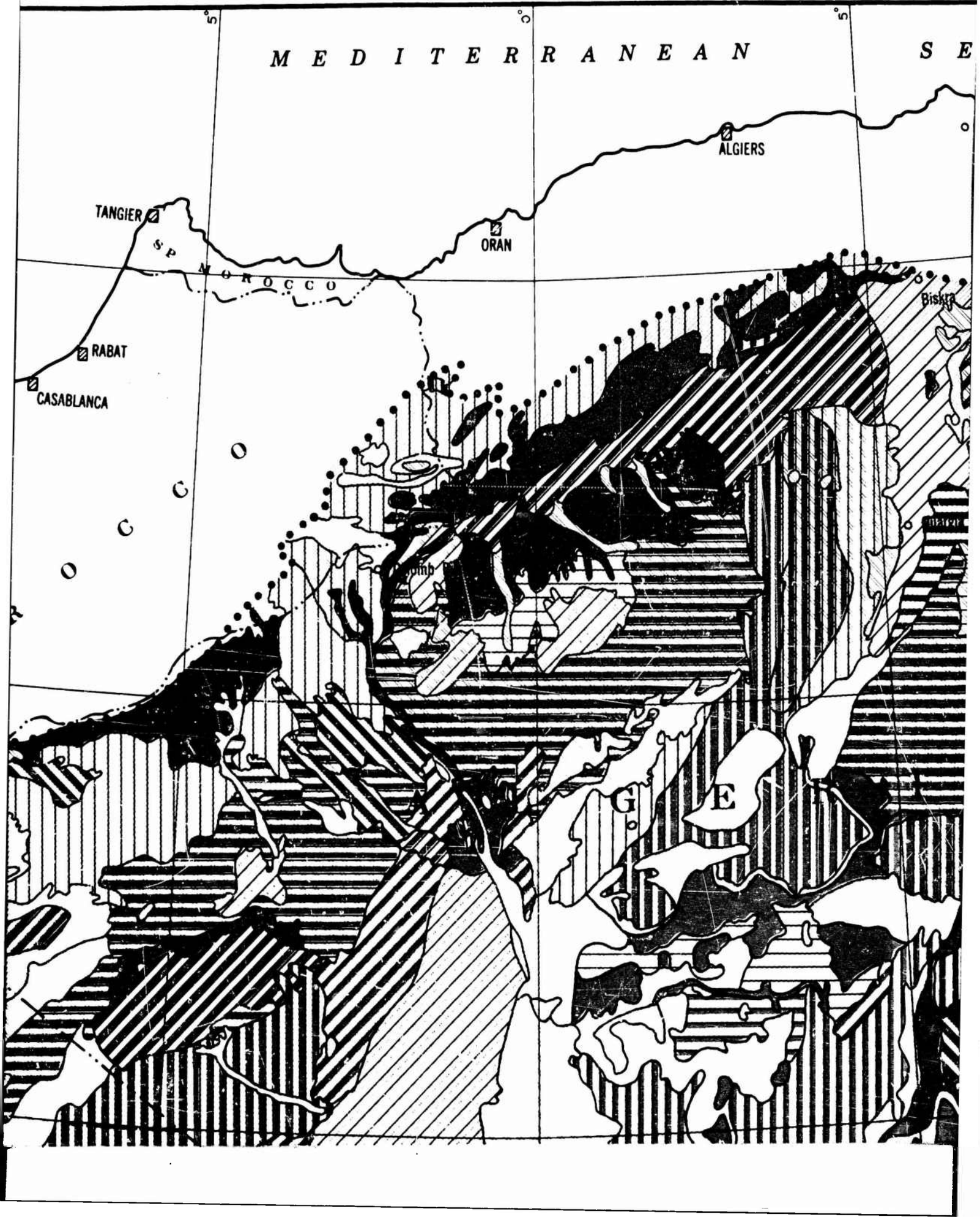
CHARACTERISTIC PLAN - PROFILE

PLATE I

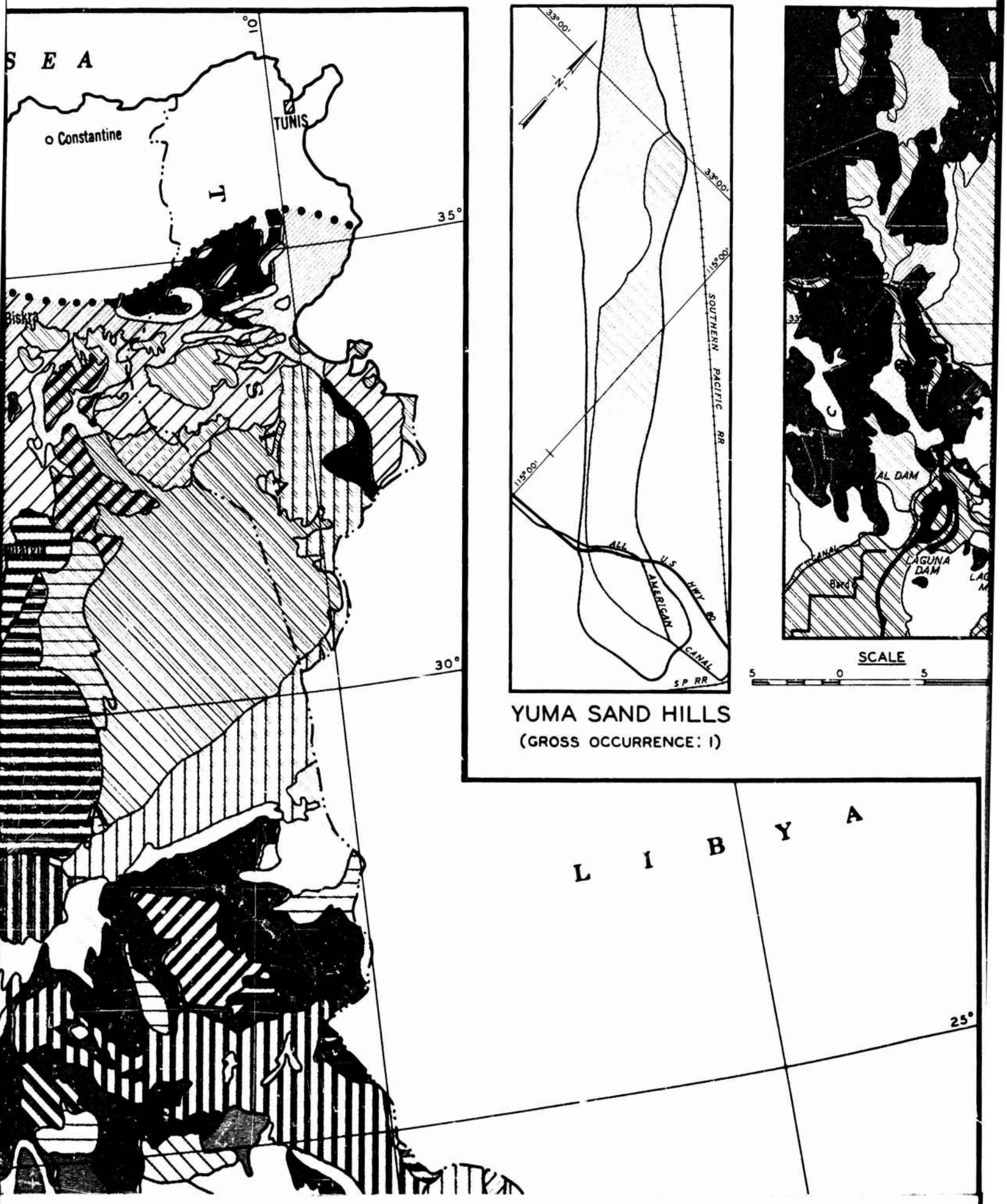
8


20°
15°
10°
35°
ATLANTIC
OCEAN
CASABLANCA
MARRAKECH
30°
25°
VILLA CISNEROS

2


MEDITERRANEAN
ALGIERS
TANGIER
ORAN
SP. MOROCCO
RABAT
CASABLANCA
Biskra

3



YUMA SAND HILLS

(GROSS OCCURRENCE: 1)

4

YUMA TEST STATION

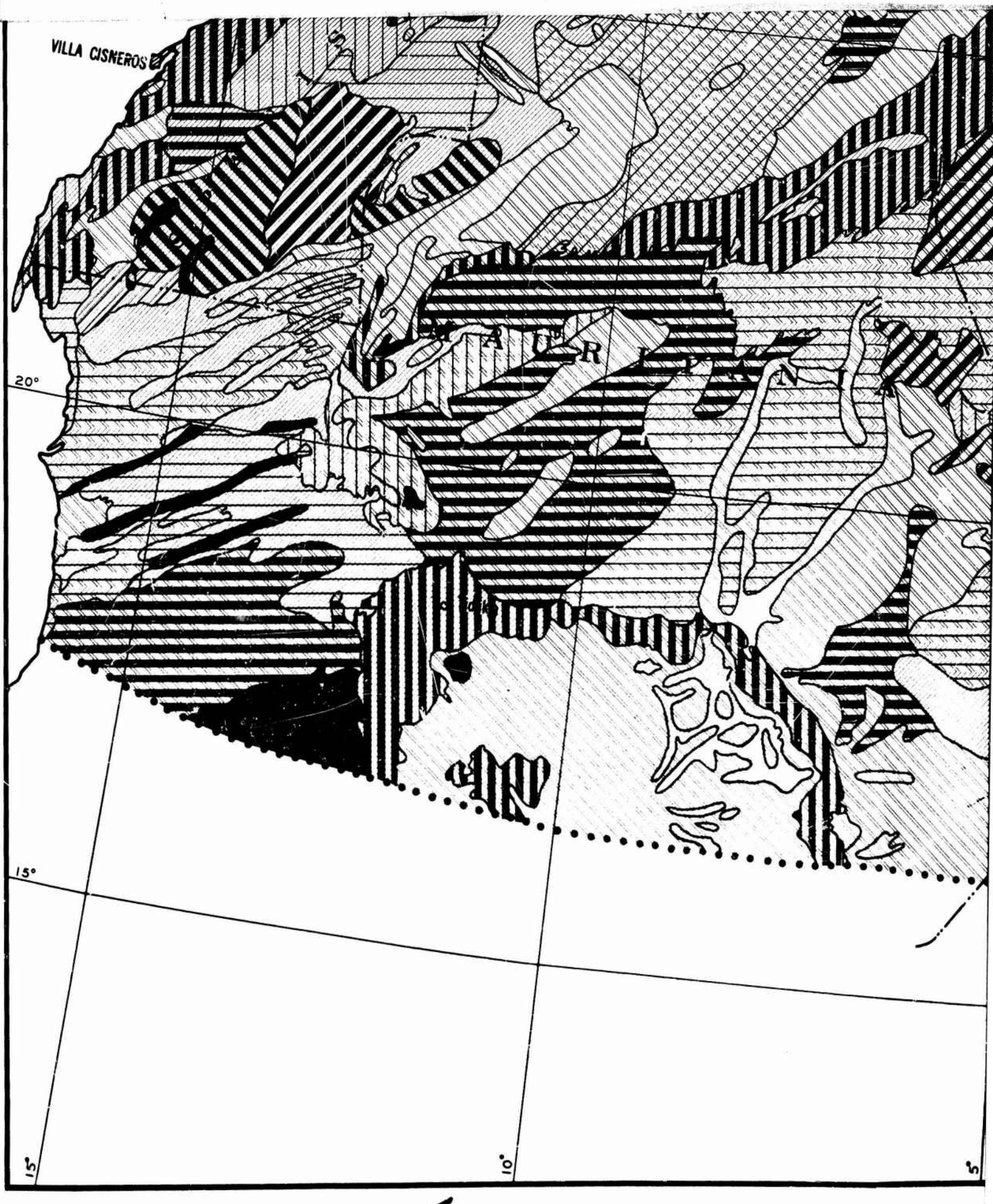
(GROSS OCCURRENCE OF COMPONENT HIGHS: 1)

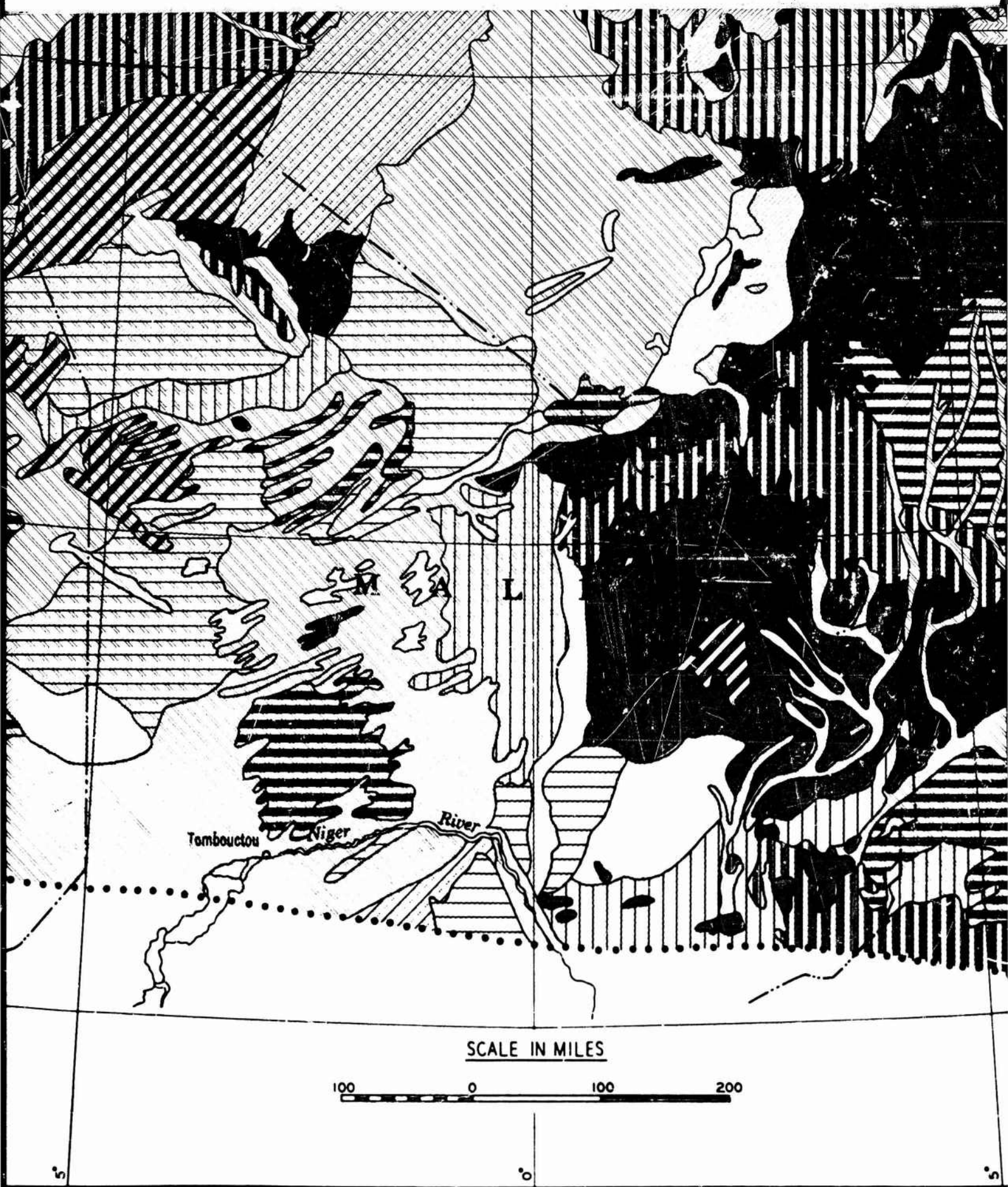
A

25°

OCCURRENCE OF SLOPES GREATER THAN 50 PER CENT

Occurrence may be either restrictive or gross. A restrictive occurrence class indicates a modal range of slopes greater than 50 per cent found along traverses containing the maximum number of such slopes. Relief of less than 10 ft is not considered. A gross occurrence indicates the modal distance between component highs or component lows. Relief of less than 100 ft is not considered.


VILLA CISNEROS
20°
15°
15°
10°
5°


M A L I
Tombouctou
Niger River
SCALE IN MILES
100 0 100 200
5°
0°
5°


20°
15°
10°
5°
NIGERIA

Occurrence may be either restrictive or gross. A restrictive occurrence class indicates a modal range of slopes greater than 50 per cent found along traverses containing the maximum number of such slopes. Relief of less than 10 ft is not considered. A gross occurrence indicates the modal distance between component highs or component lows. Relief of less than 100 ft is not considered.

1 The number of slopes steeper than 50 per cent is less than 1 per 10 miles or in areas, less than 10 miles in maximum dimension, where such slopes are lacking.

2 The number of slopes steeper than 50 per cent ranges from 1 to 5 per 10 miles.

3 The number of slopes steeper than 50 per cent ranges from 5 to 20 per 10 miles.

4 The number of slopes steeper than 50 per cent ranges from 20 to 100 per 10 miles.

5 The number of slopes steeper than 50 per cent ranges from 100 to 200 per 10 miles.

6 The number of slopes steeper than 50 per cent exceeds 200 per 10 miles.

OCCURRENCE COMPLEXES: (Mapped only where plan-profile complexes are mapped.)

Areal Complexes: Confined to areas where two major, areally restricted occurrence units, both of the restrictive type, are mapped.

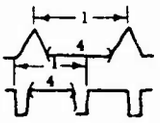
3/5 Slope occurrence of areally predominant lows.
Slope occurrence of areally subordinate highs.

1\3 Slope occurrence of areally predominant highs.
Slope occurrence of areally subordinate lows.

Gross-component Complexes: Mapped only where gross-component plan-profile complexes are mapped.

1/4 Gross occurrence of component highs.
Restrictive occurrence within component lows.

1|4 Gross occurrence of component lows.
Restrictive occurrence within component highs.



ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

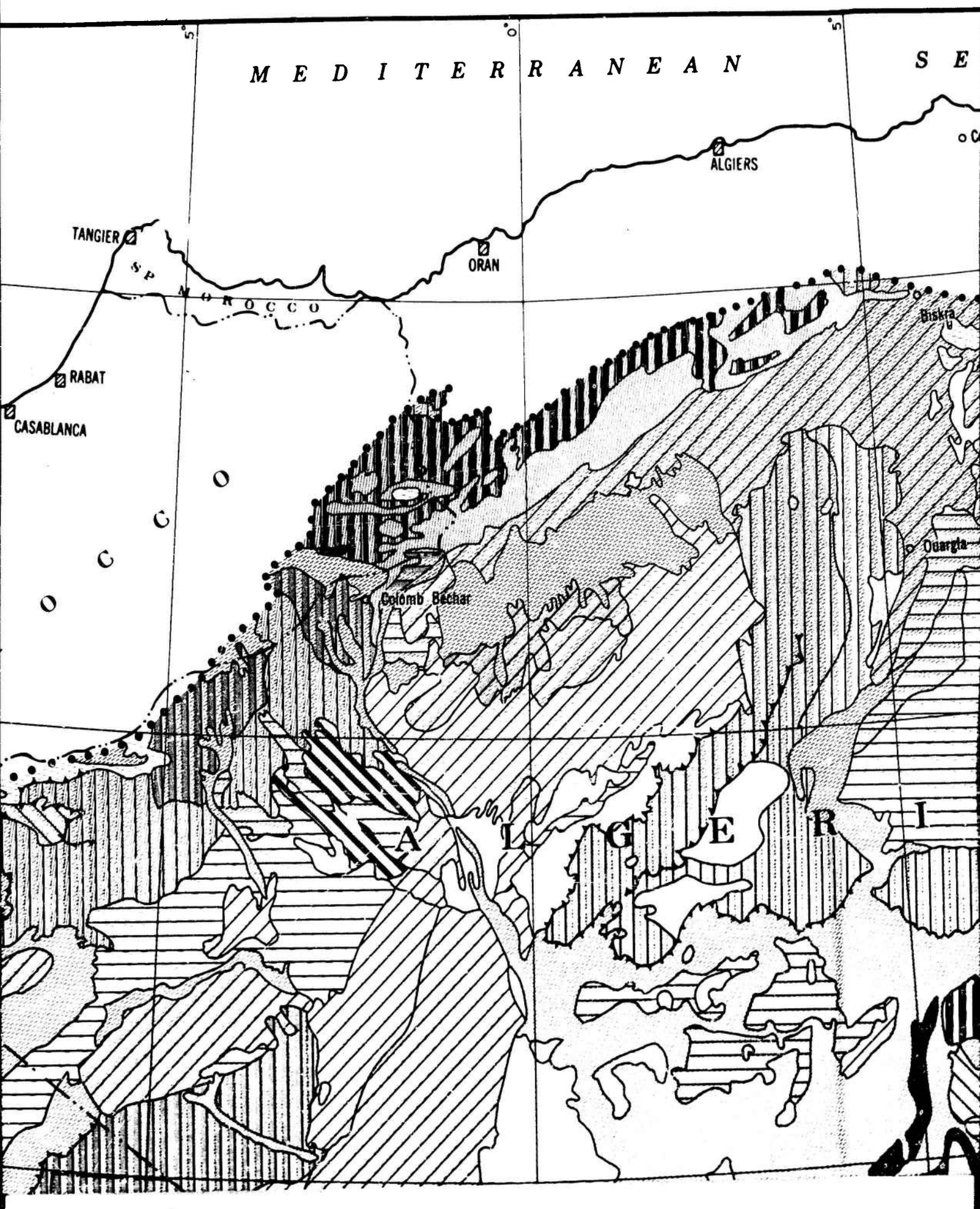
OCCURRENCE OF SLOPES GREATER THAN 50 PER CENT

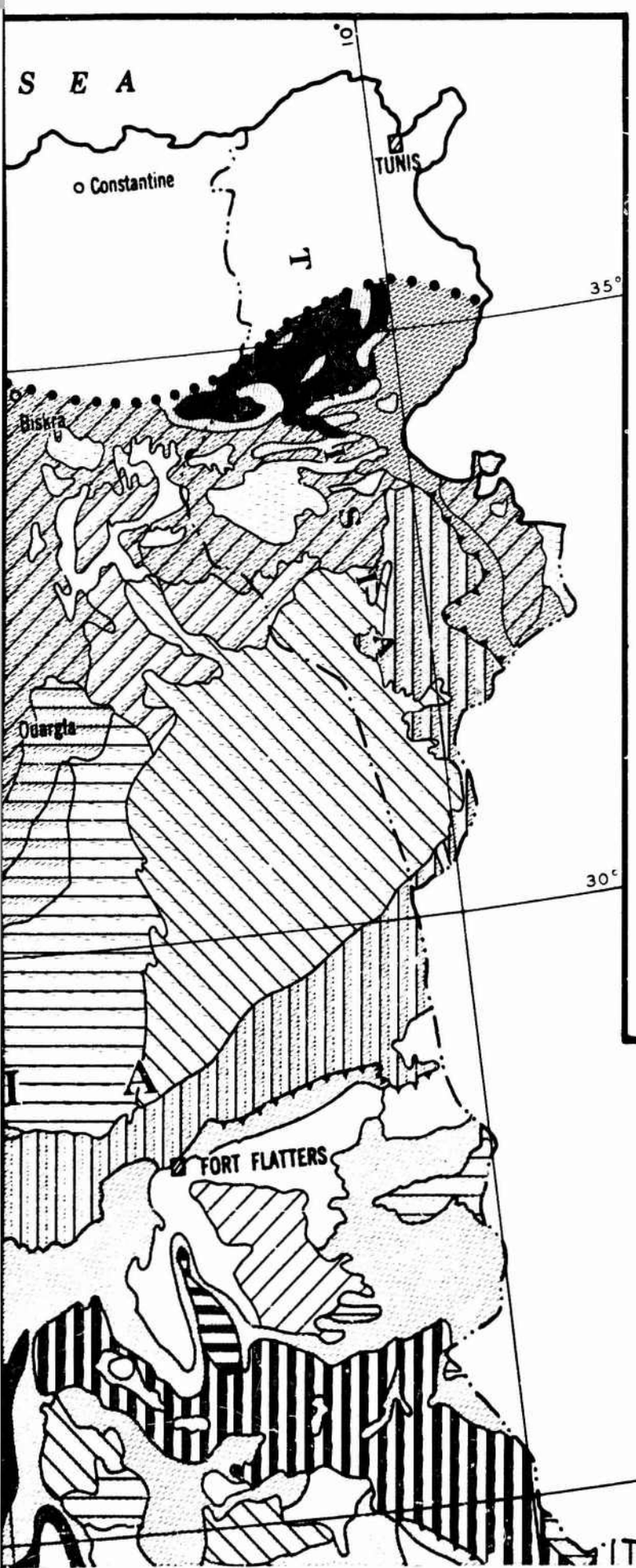
PLATE 2

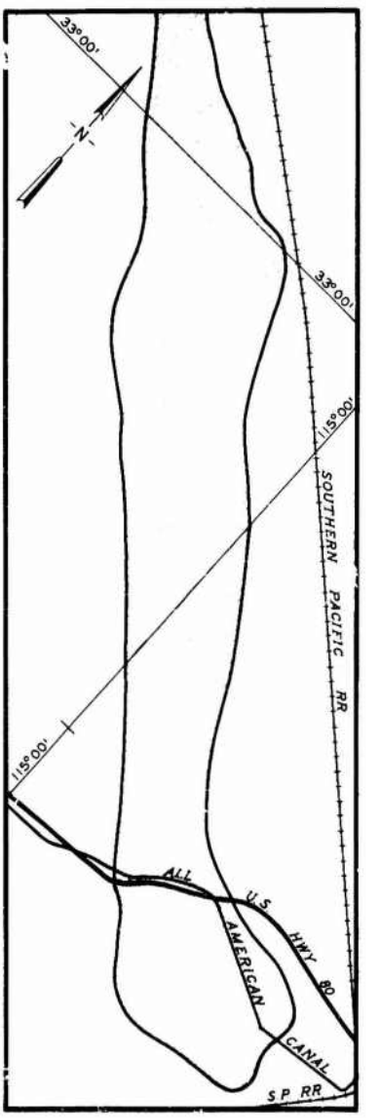
8

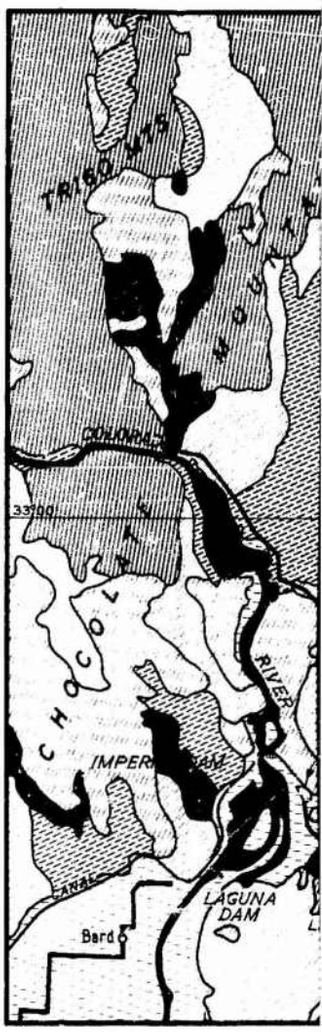

20°
15°
10°
35°
ATLANTIC
OCEAN
CASABL
MARRAKECH
30°
25°
VILLA CISNEROS

2


MEDITERRANEAN
SE
ALGIERS
TANGIER
ORAN
SP
MOROCCO
RABAT
CASABLANCA
Biskra
Ouargla
Colomb Bechar
ALGERIA







SCALE

5 0 5

YUMA SAND HILLS
(CHARACTERISTIC SLOPE: 3)

4

SCALE

5 10 MI.

YUMA TEST STATION

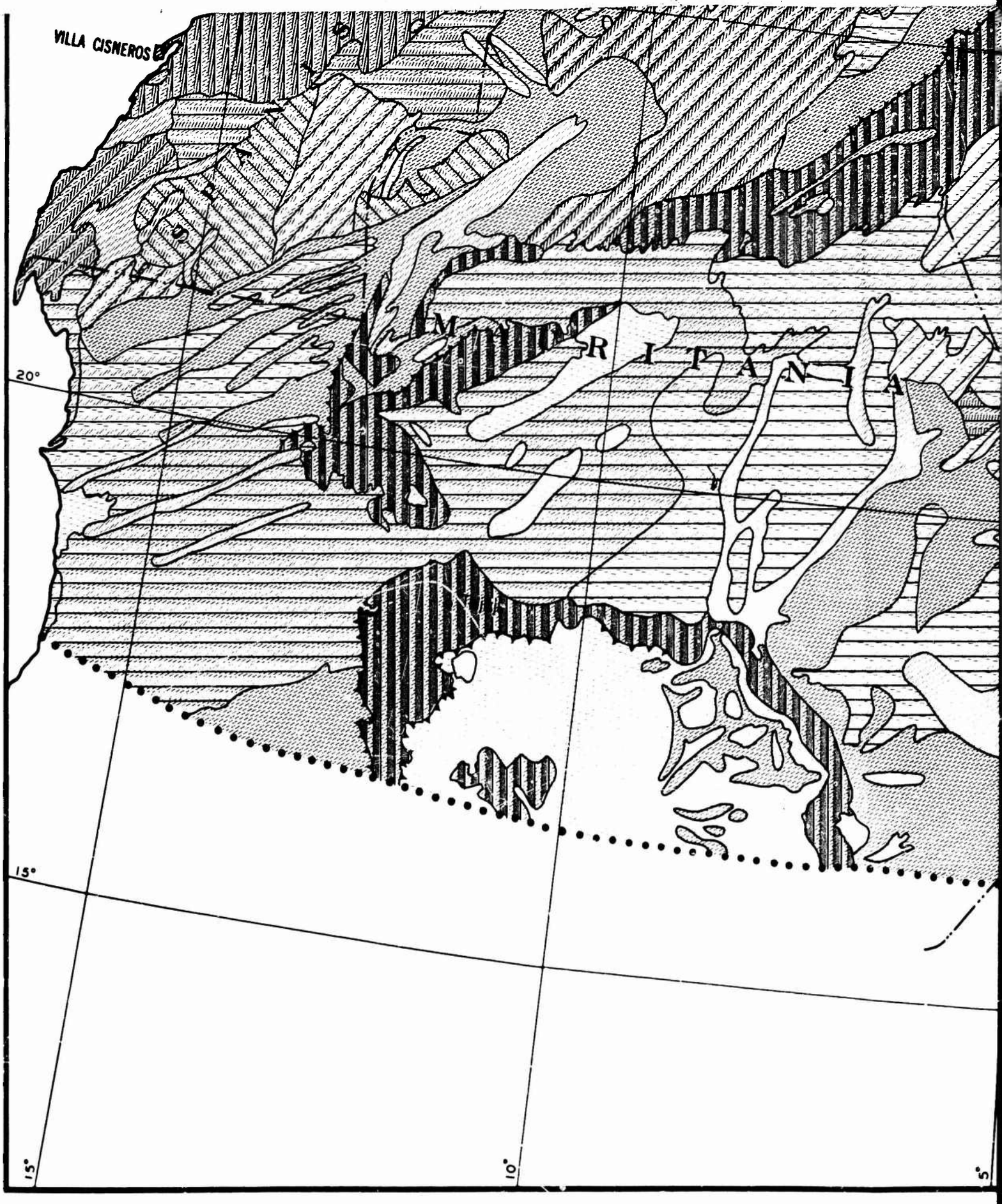
(CHARACTERISTIC SLOPE WITHIN COMPONENT HIGHS: 5)

25°

CHARACTERISTIC SLOPE

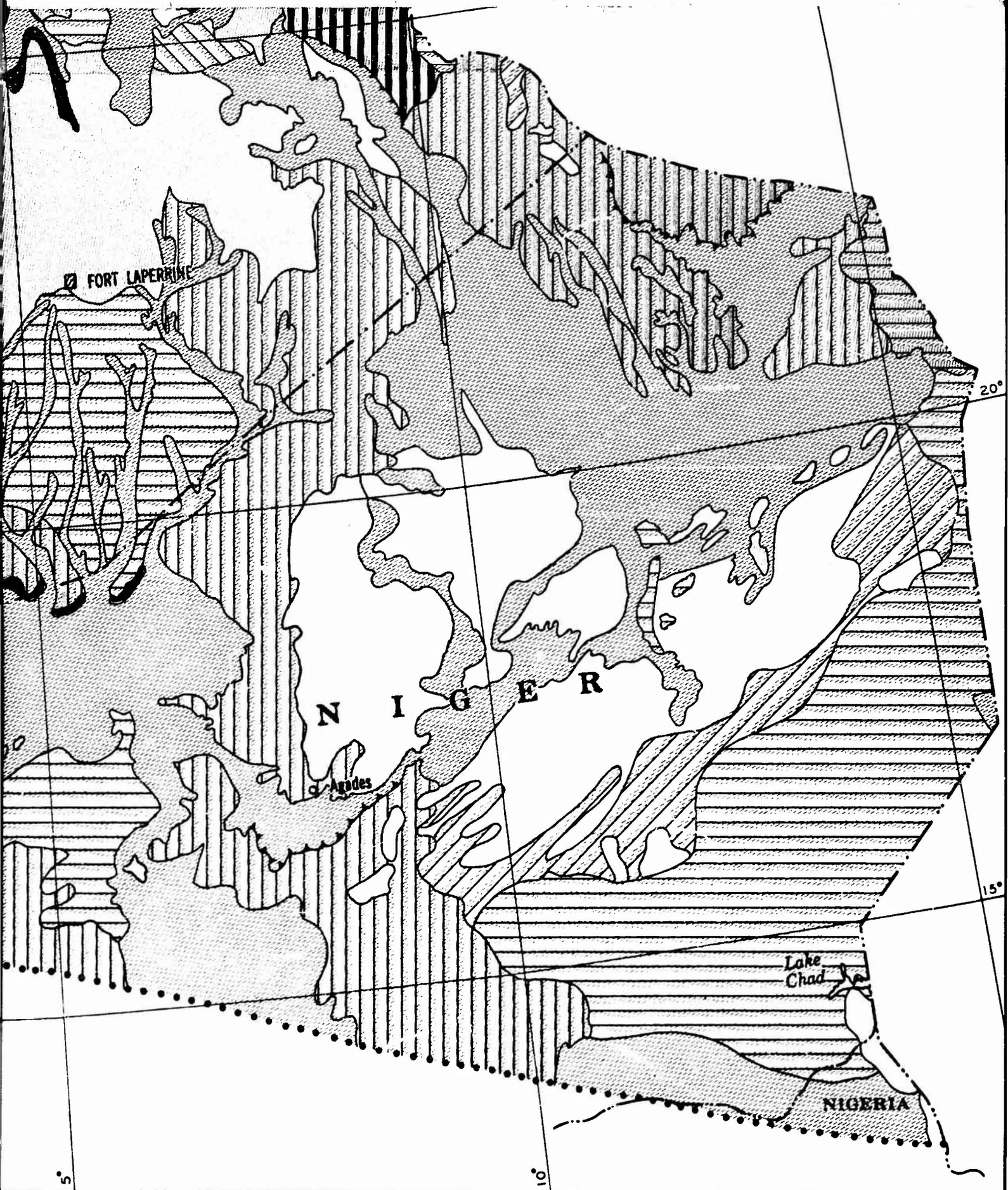
Slope is defined as a surface identified or designated in terms of its deviation from the horizontal. Characteristic slope is defined as a narrow range of slopes which predominates or is most common within a region (possessing a distinctive spacing, arrangement, or pattern of contour lines) mapped with a 10-ft contour interval.

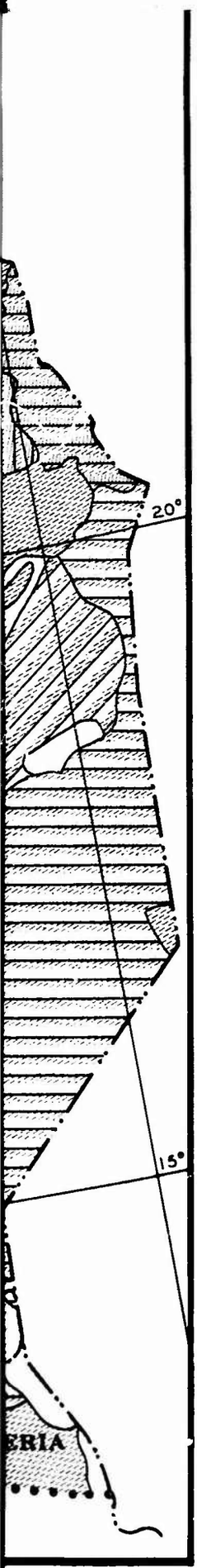
Flat: Characteristic slope between 0 and 2 degrees (approx. 0 - 3.5%).



ی


M A L I
Tombouctou
Niger River
SCALE IN MILES
100 0 100 200
5°
0°
5°


FORT LAPERRINE
20°
N I G E R
Agades
15°
Lake Chad
NIGERIA
5°
10°



(possessing a distinctive spacing, arrangement, or pattern of contour lines) mapped with a 10-ft contour interval.

Flat: Characteristic slope between 0 and 2 degrees (approx. 0 - 3.5%).

1a — Between 0 and 1/2 degree (approx. 0 - 1%).

1b — Between 1/2 and 2 degrees (approx. 1 - 3.5%).

2 — Gentle: Characteristic slope between 2 and 6 degrees (approx. 3.5 - 10%).

3 — Moderate: Characteristic slope between 6 and 14 degrees (approx. 10 - 25%).

4 — Declivitous: Characteristic slope between 14 and 26.5 degrees (approx. 25 - 50%).

5 — Steep: Characteristic slope between 26.5 and 45 degrees (approx. 50 - 100%).

6 — Precipitous: Characteristic slope greater than 45 degrees (greater than 100%).

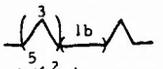
SLOPE COMPLEXES: (Mapped only where plan-profile complexes are mapped)
Areal Complexes: Confined to areas where two major, areally restricted slope types are mapped.

2/4 — Characteristic slope of areally predominant lows.
Characteristic slope of areally subordinate highs.

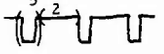
1b\3 — Characteristic slope of areally predominant highs.
Characteristic slope of areally subordinate lows.

Gross-component Complexes: Mapped only where gross-component plan-profile complexes are mapped. The symbols in the complex are arranged vertically or horizontally depending on the plan-profile.

3/1b — Characteristic slope within component highs.*
Characteristic slope within component lows.



5|2 — Characteristic slope within component lows.*
Characteristic slope within component highs.



Important Scarps: An important scarp is defined as a more or less continuous precipitous slope exhibiting more than 100 feet of relief. Only the better known scarps which extend for considerable distances have been mapped. Scarp height is indicated where known.

* In cases where the gross plan-profile is flat-topped or flat-bottomed the characteristic slope is considered to be the modal slope of the bounding inclines.

ANALOGS OF YUMA TERRAIN

IN THE

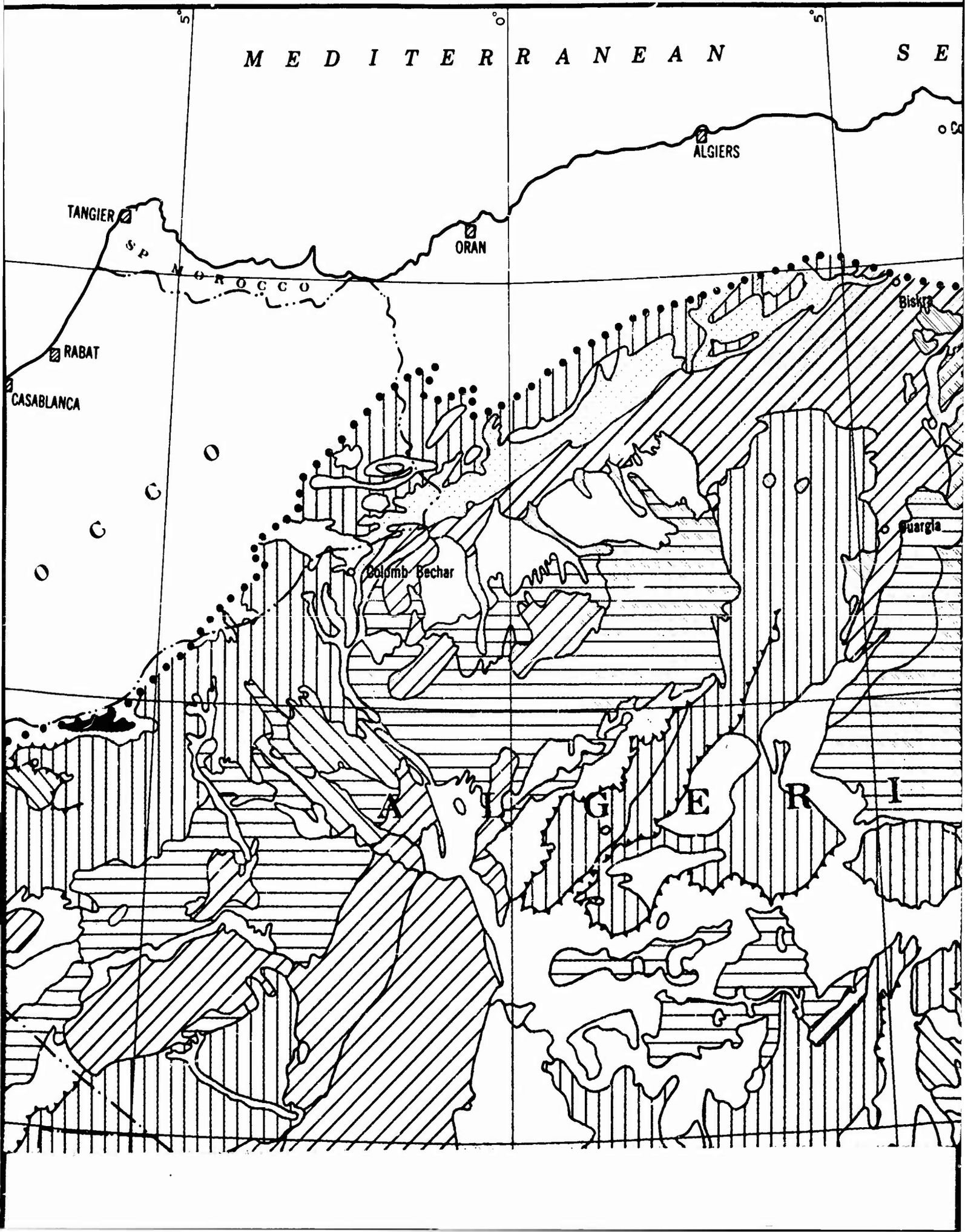
NORTHWEST AFRICAN DESERT

CHARACTERISTIC SLOPE

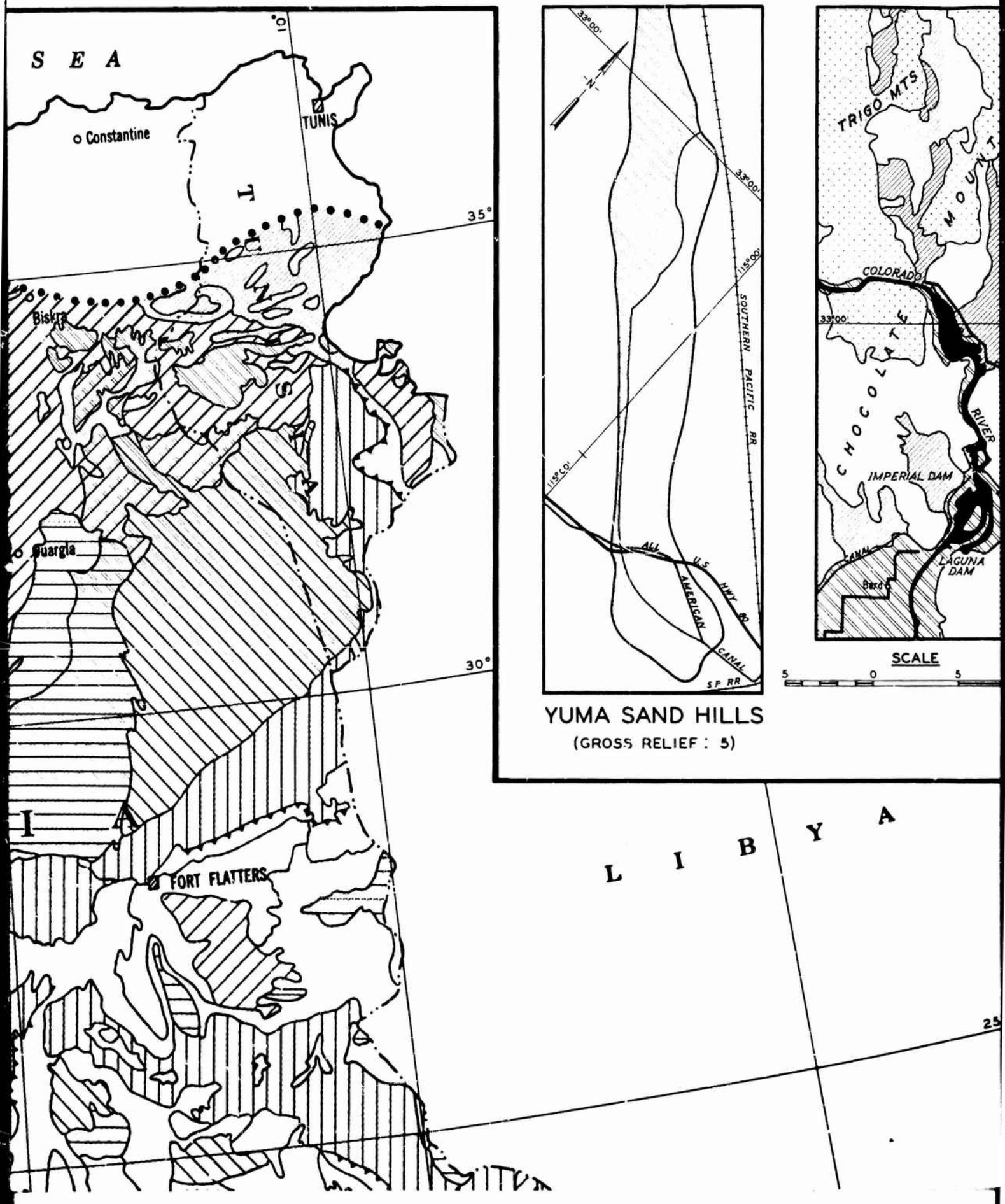
PLATE 3


20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
MARRAKECH
CASABLANCA
VILLA CISNEROS
SAHARA

2


MEDITERRANEAN
ALGIERS
TANGIER
ORAN
MOROCCO
RABAT
CASABLANCA
Biskra
Ouargla
Colomb Bechar
ALGERIA

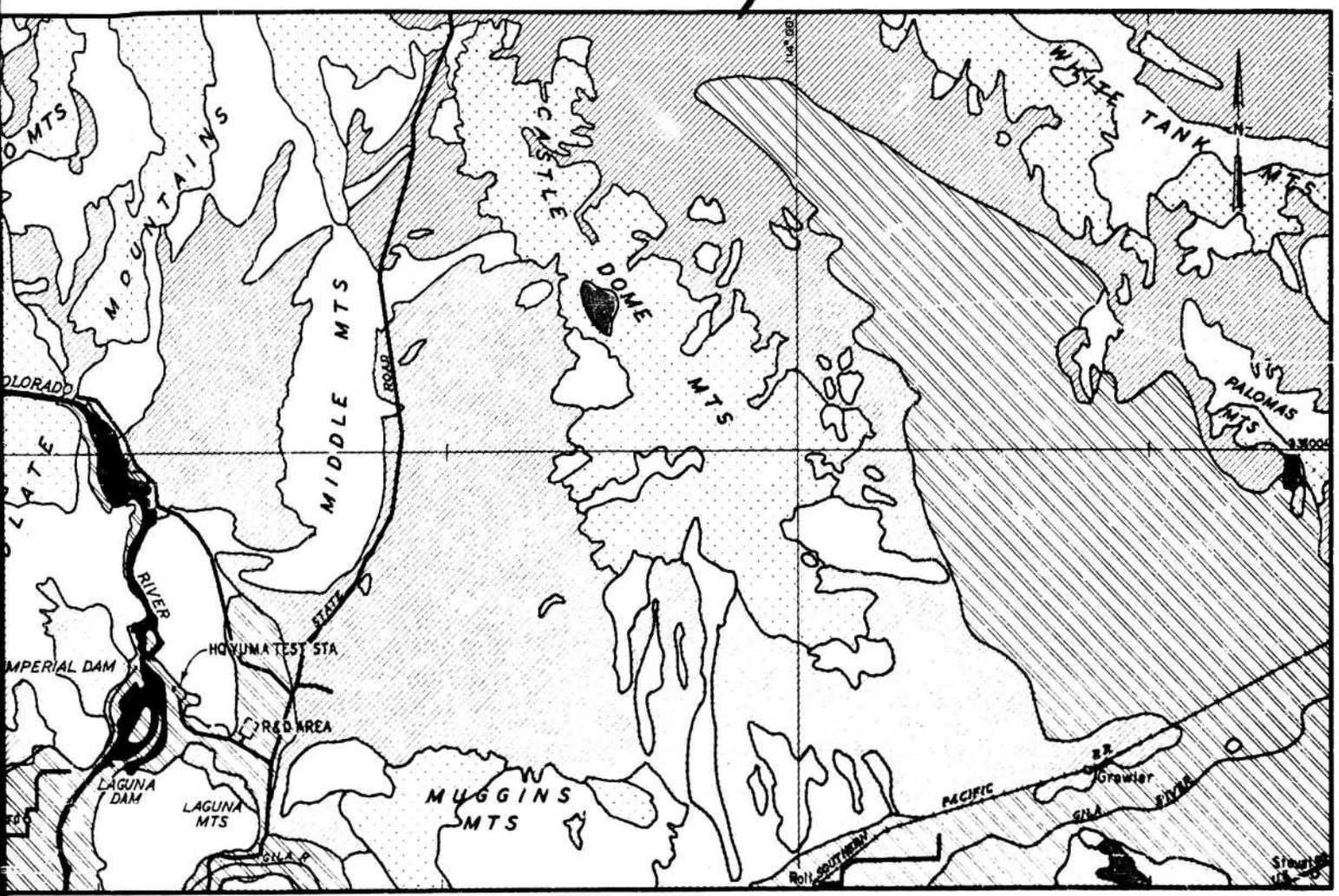
3



YUMA SAND HILLS

(GROSS RELIEF : 5)

4



SCALE

0 5 10 MI.

YUMA TEST STATION

(GROSS RELIEF OF COMPONENT HIGHS : 7)

A

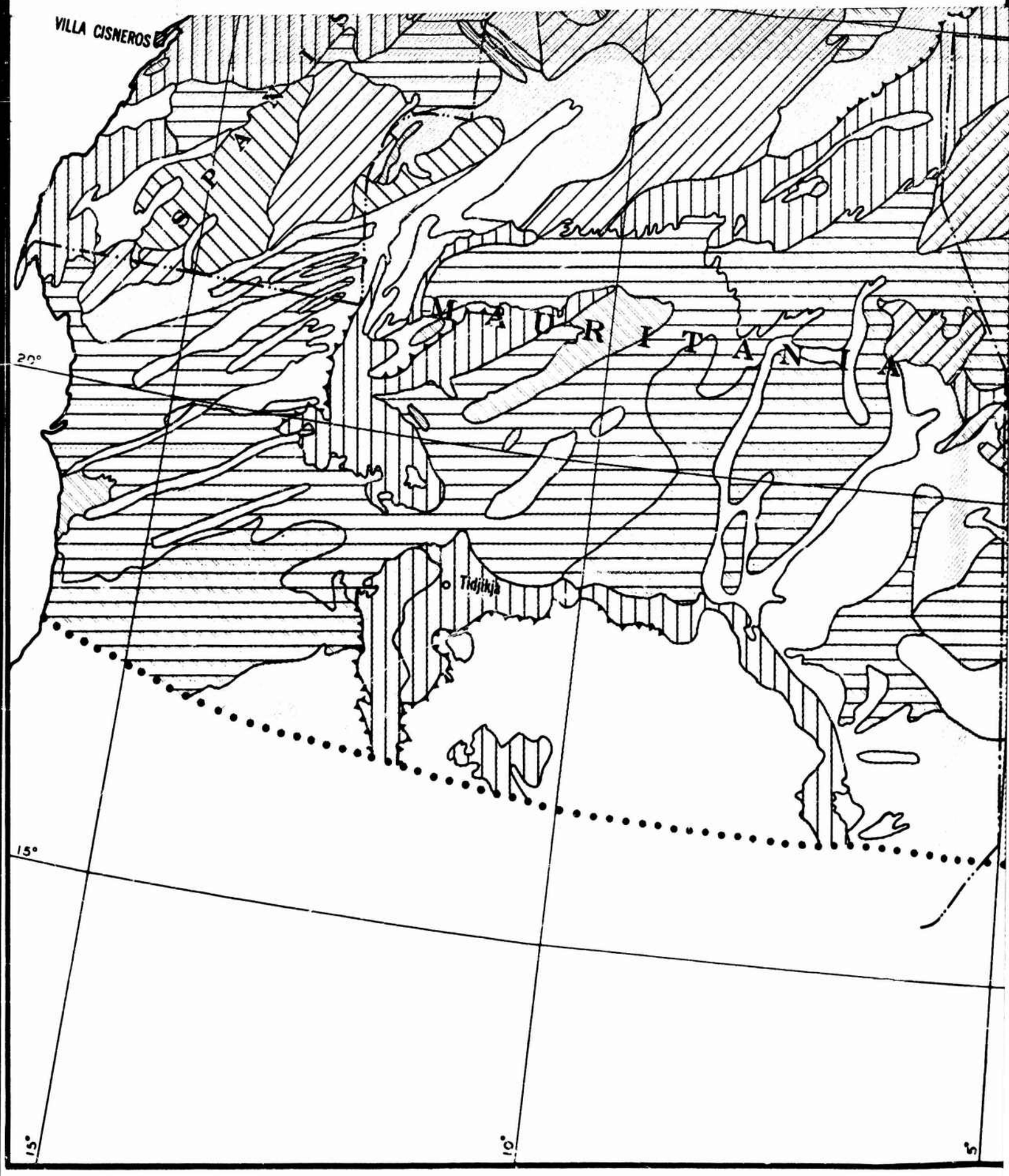
25°

CHARACTERISTIC RELIEF

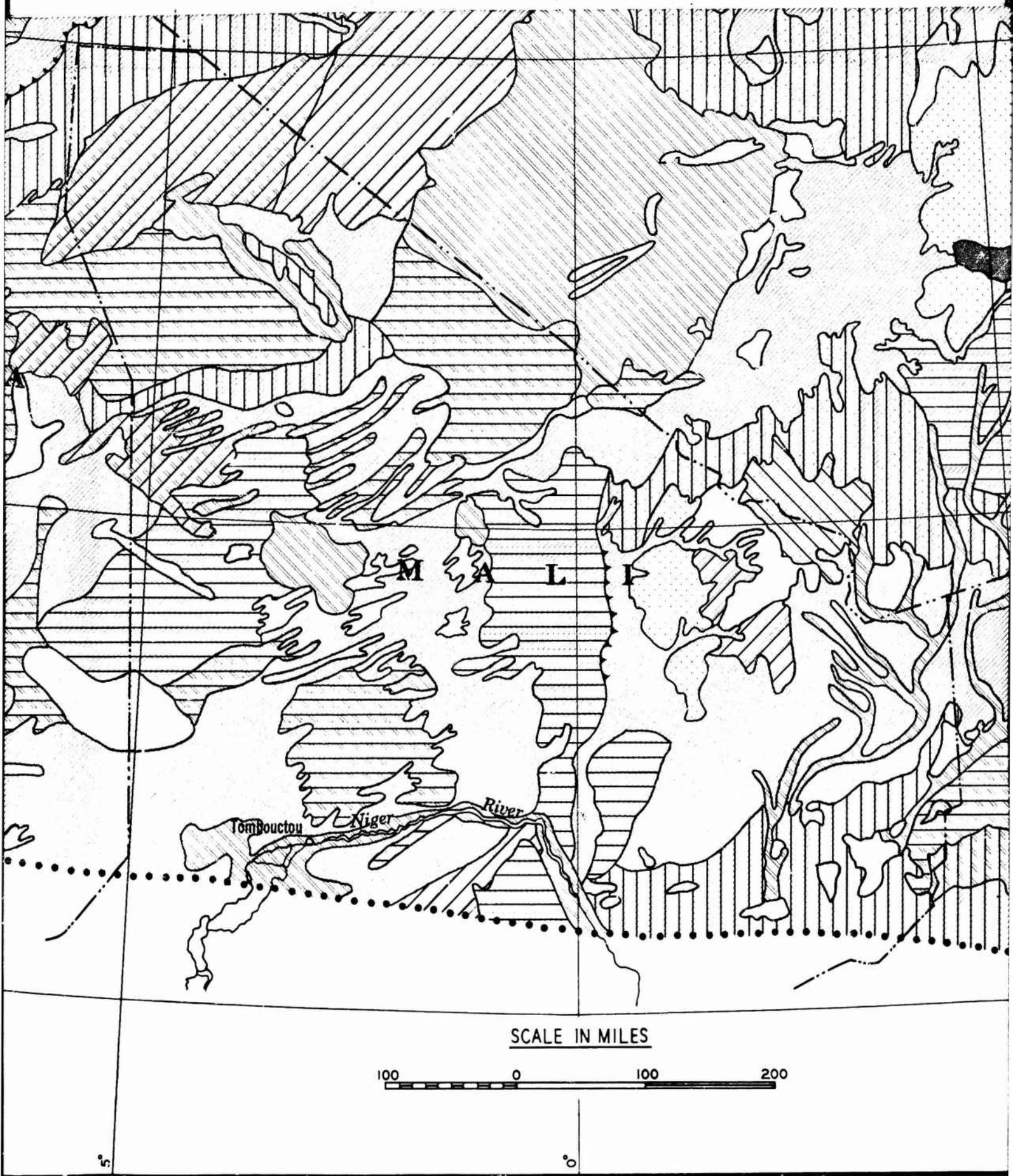
Characteristic relief may be either restrictive or gross. Restrictive relief is based on modal classes of stream depth, elevation differential per unit area, or prominence height. This is further defined under type I and type II relief, below. Gross relief indicates the modal height of component highs or the modal depth of component lows.

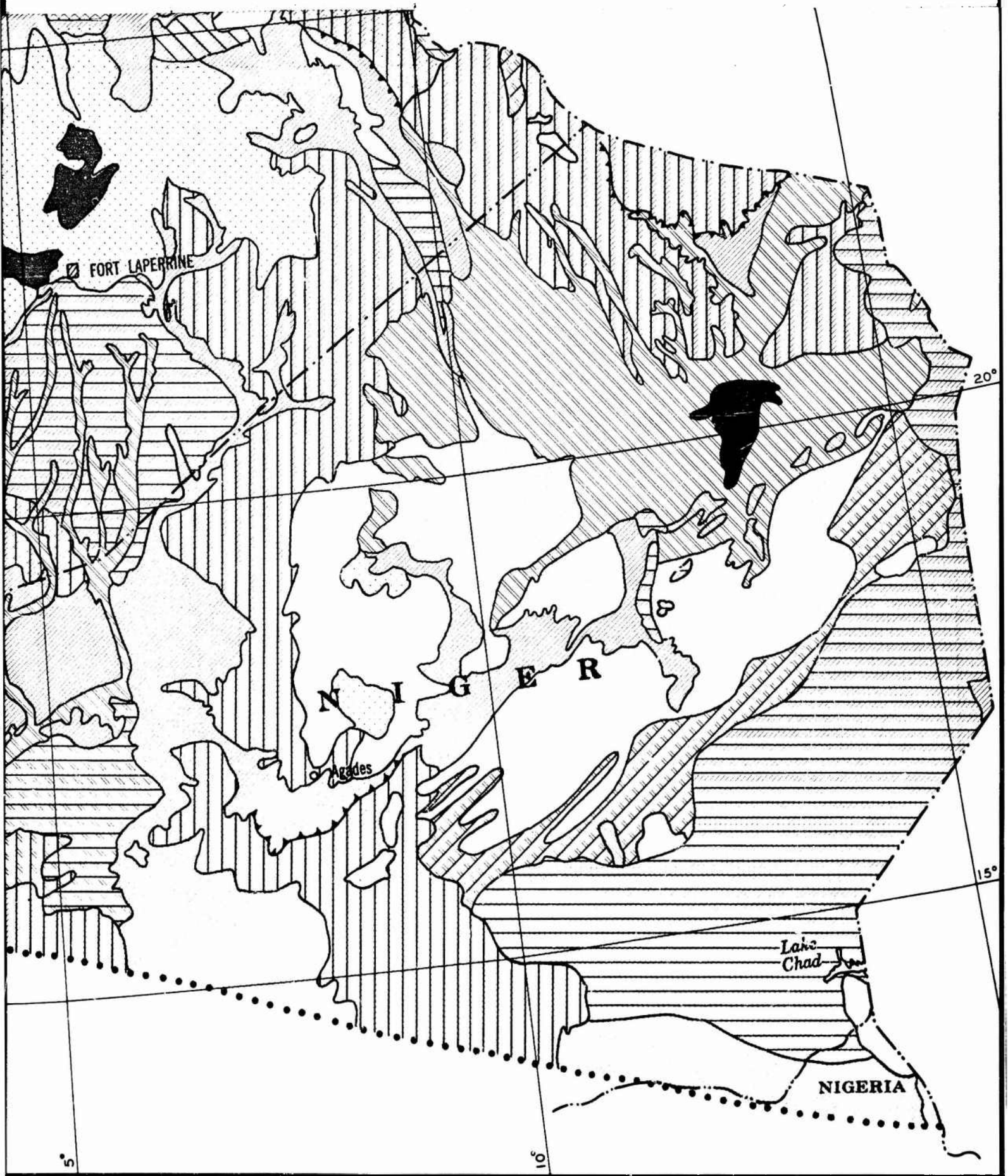
1. **RELIEF IN AREAS WHERE THE CHARACTERISTIC SLOPE IS LESS THAN 6 DEGREES (APPROX. 10 PER CENT)**

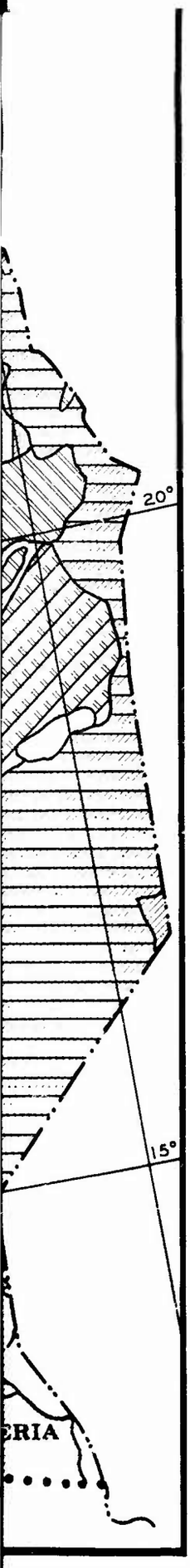
Relief is defined as the modal vertical distance from interfluve crest to the immediately adjacent flow line, or in areas where drainage lines are poorly developed or lacking,* from summit to adjacent low.



ک


M A L I
Niger River
Tombouctou
SCALE IN MILES
100 0 100 200
5°
0°


FORT LAPERRINE
20°
N I G E R
Agades
15°
Lake Chad
NIGERIA
5°
10°



Relief is defined as the modal vertical distance from interfluve crest to the immediately adjacent flow line, or in areas where drainage lines are poorly developed or lacking,* from summit to adjacent low.

1 Characteristic relief between 0 and 10 feet.

2 Characteristic relief between 10 and 50 feet.

3 Characteristic relief > 50 feet.

II. RELIEF IN AREAS WHERE THE CHARACTERISTIC SLOPE IS GREATER THAN 6 DEGREES (APPROX. 10 PER CENT)

Relief is defined as the modal maximum difference in elevation per square mile, or in areas where drainage lines are poorly developed or lacking,* from summit to adjacent low.

* Usually restricted to sand dune areas—maximum height of dunes indicated where known.

4 Characteristic relief between 0 and 100 feet.

5 Characteristic relief between 100 and 400 feet.

6 Characteristic relief between 400 and 1,000 feet.

7 Characteristic relief greater than 1,000 feet.

RELIEF COMPLEXES: (Mapped only where plan-profile complexes are mapped.)

Areal Complexes: Confined to areas where two major, areally restricted relief units, both of the restrictive type, are mapped.

2/5 Relief of areally predominant lows.
Relief of areally subordinate highs.

2\5 Relief of areally predominant highs.
Relief of areally subordinate lows.

Gross-component Complexes: Mapped only where gross-component plan-profile complexes are mapped.

5/1 Gross relief of component highs.
Restrictive relief within component lows.

5|2 Gross relief of component lows.
Restrictive relief within component highs.

Important Scarps: A scarp is defined as a more or less continuous precipitous slope exhibiting more than 100 feet of relief. Only the better known scarps which extend for considerable distances have been mapped. Scarp height is indicated where known.

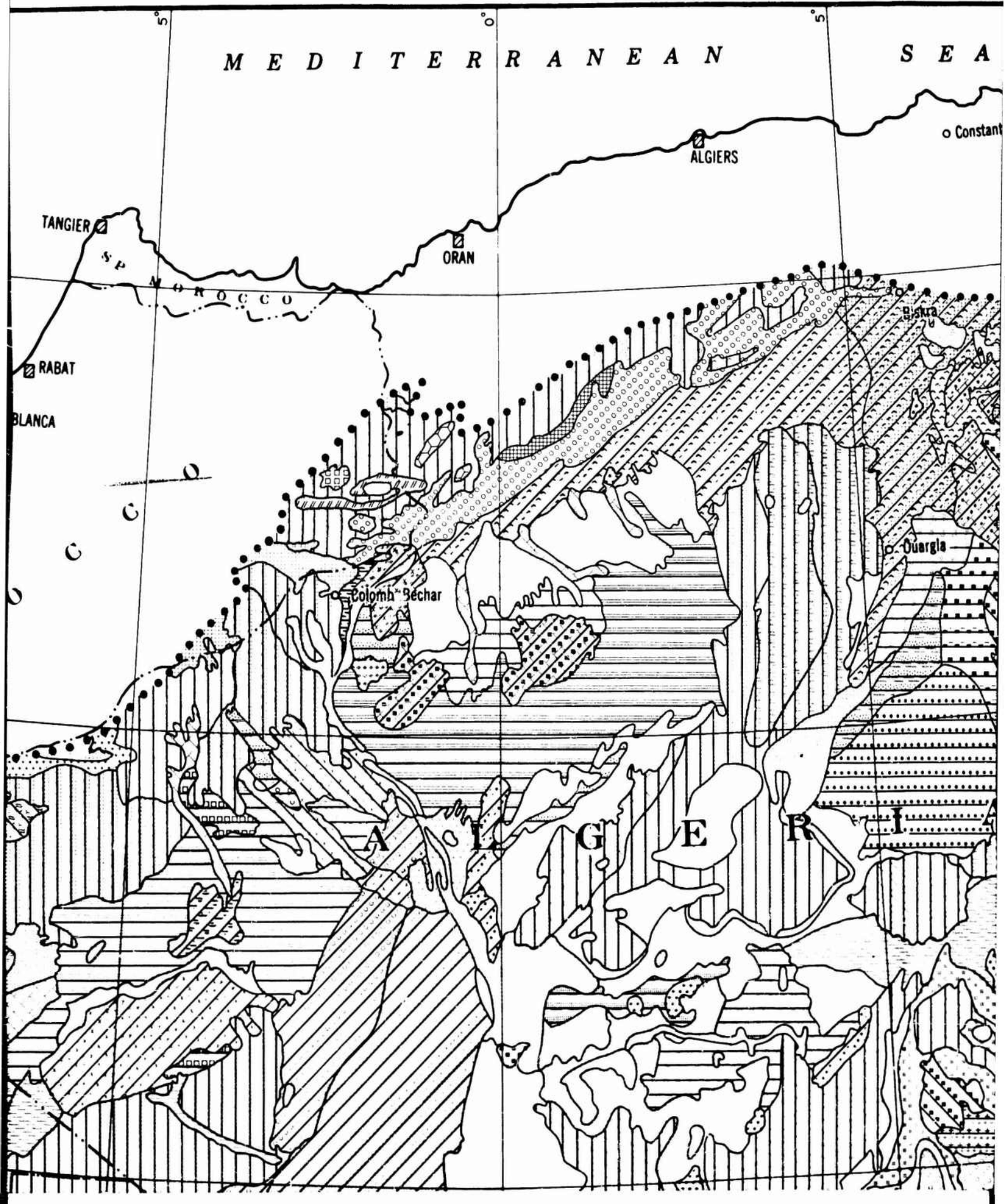
ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

CHARACTERISTIC RELIEF

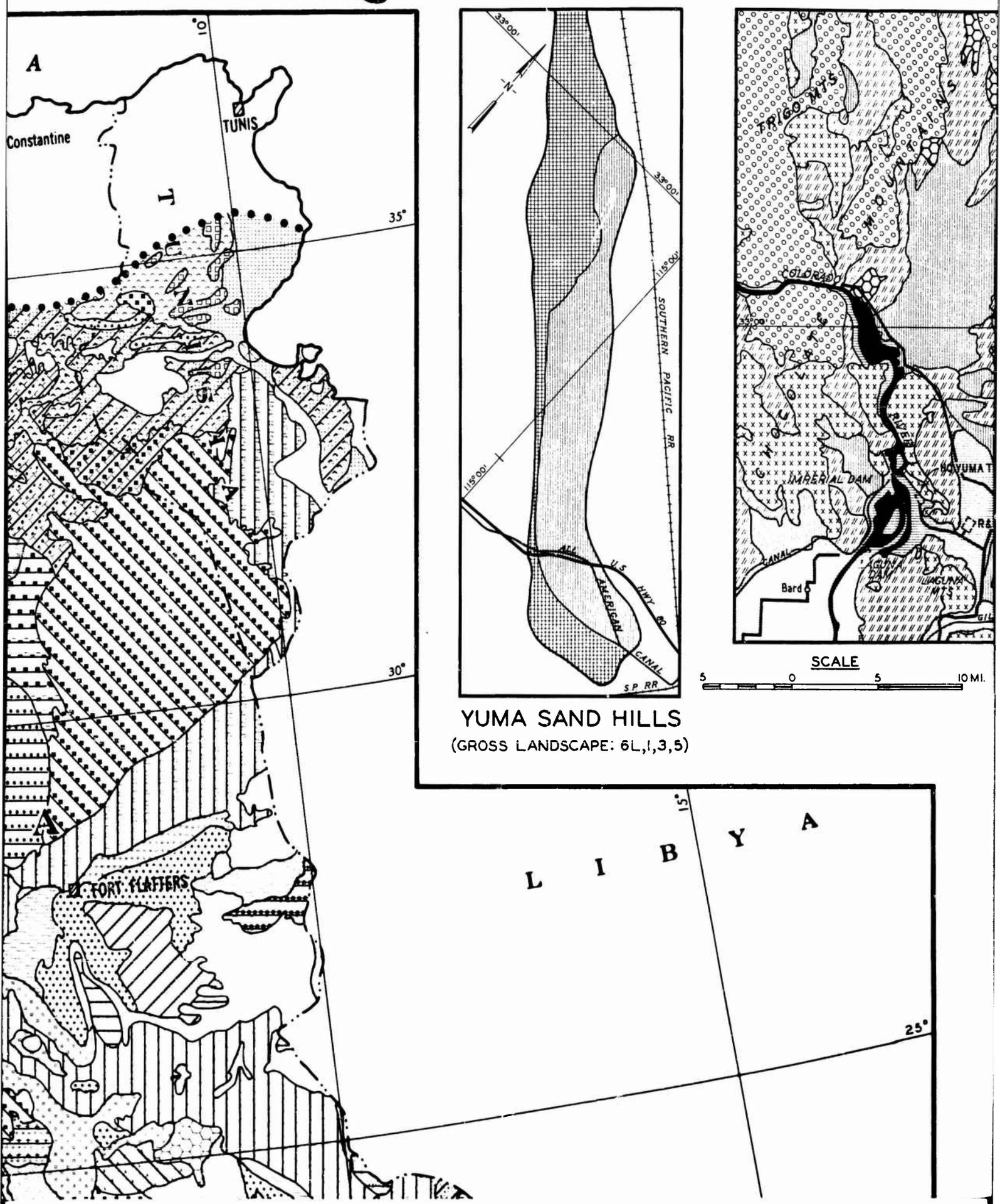
PLATE 4


20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
CASABLAN
MARRAKECH
Mogador
M O R O
SAHARA
SPANISH
VILLA CISNEROS

2


MEDITERRANEAN SEA
5°
0°
5°
ALGIERS
Constant
TANGIER
ORAN
SP. MOROCCO
Biskra
RABAT
BLANCA
Ouargla
Colomb Béchar
ALGERIA

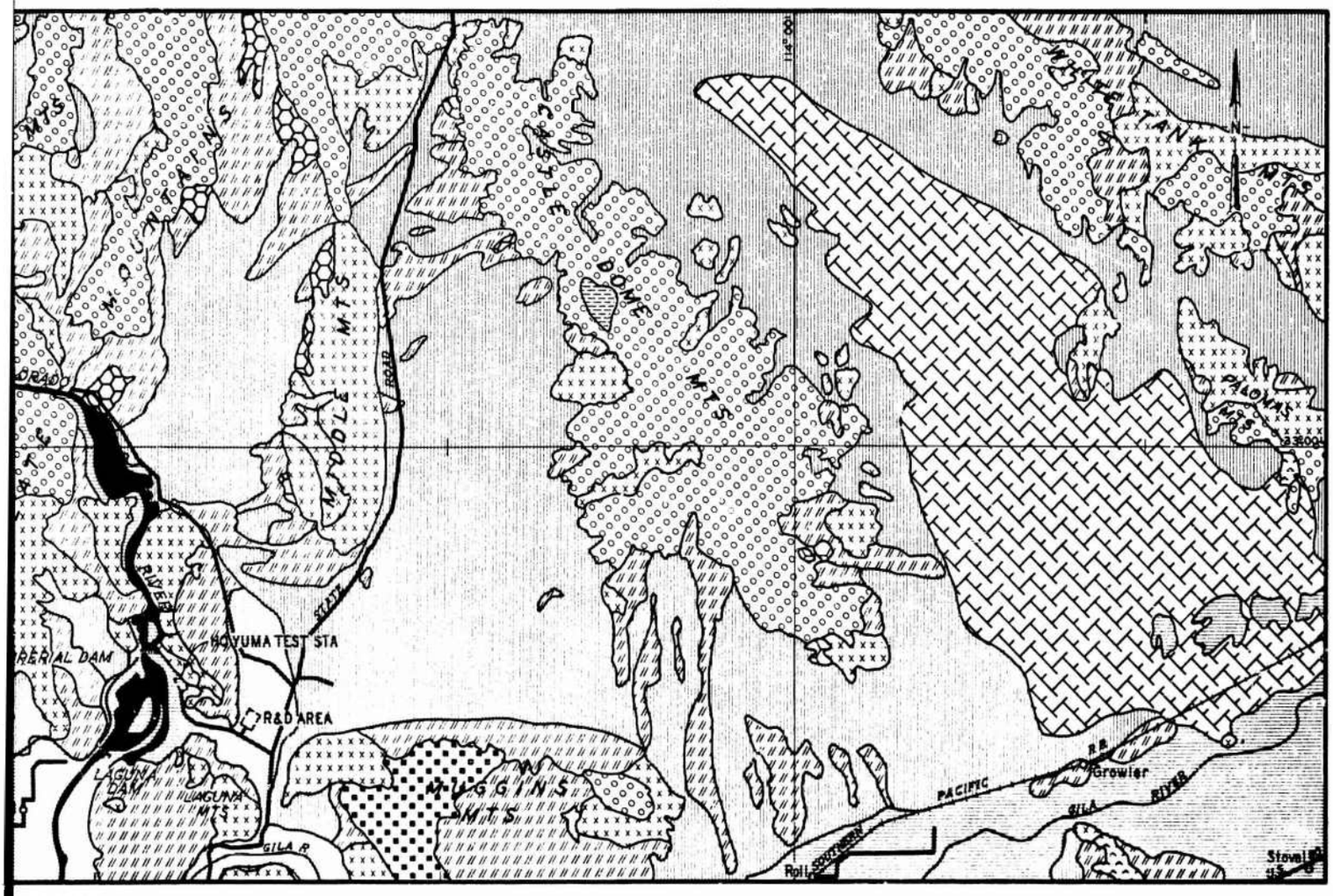
3



YUMA SAND HILLS

(GROSS LANDSCAPE: 6L,!,3,5)

4



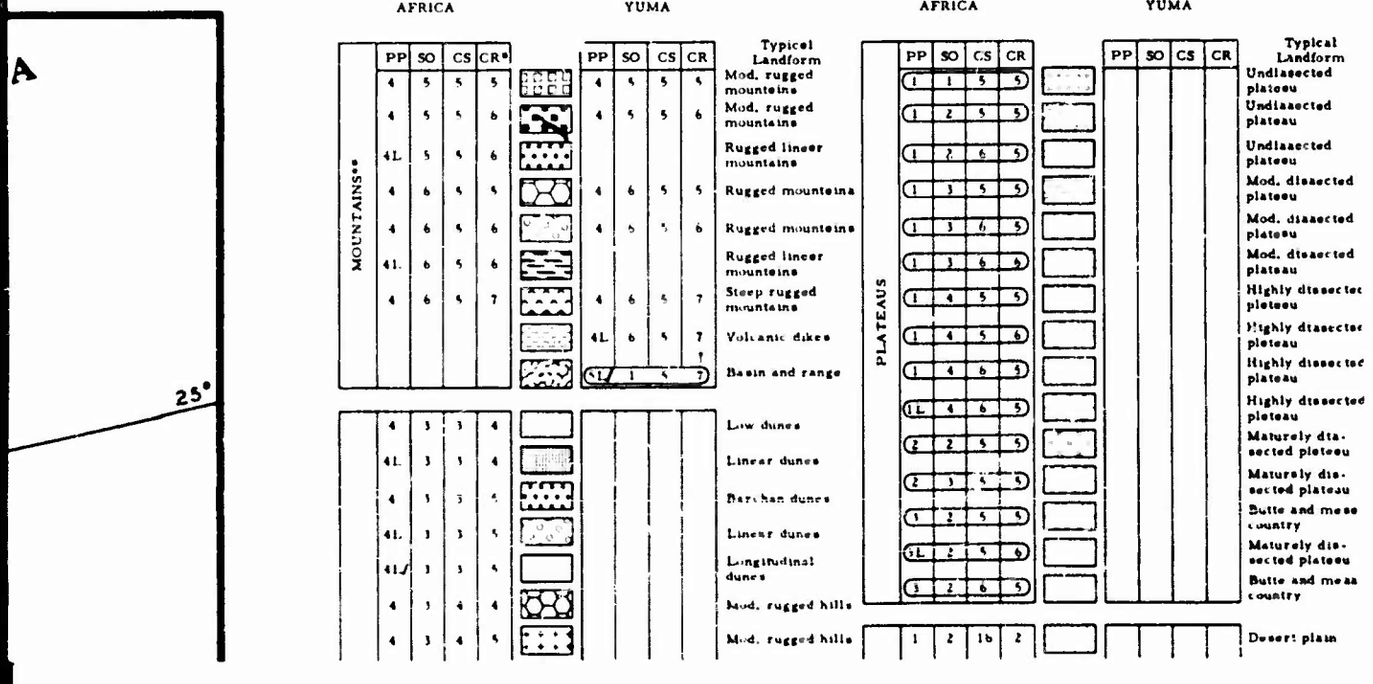
SCALE

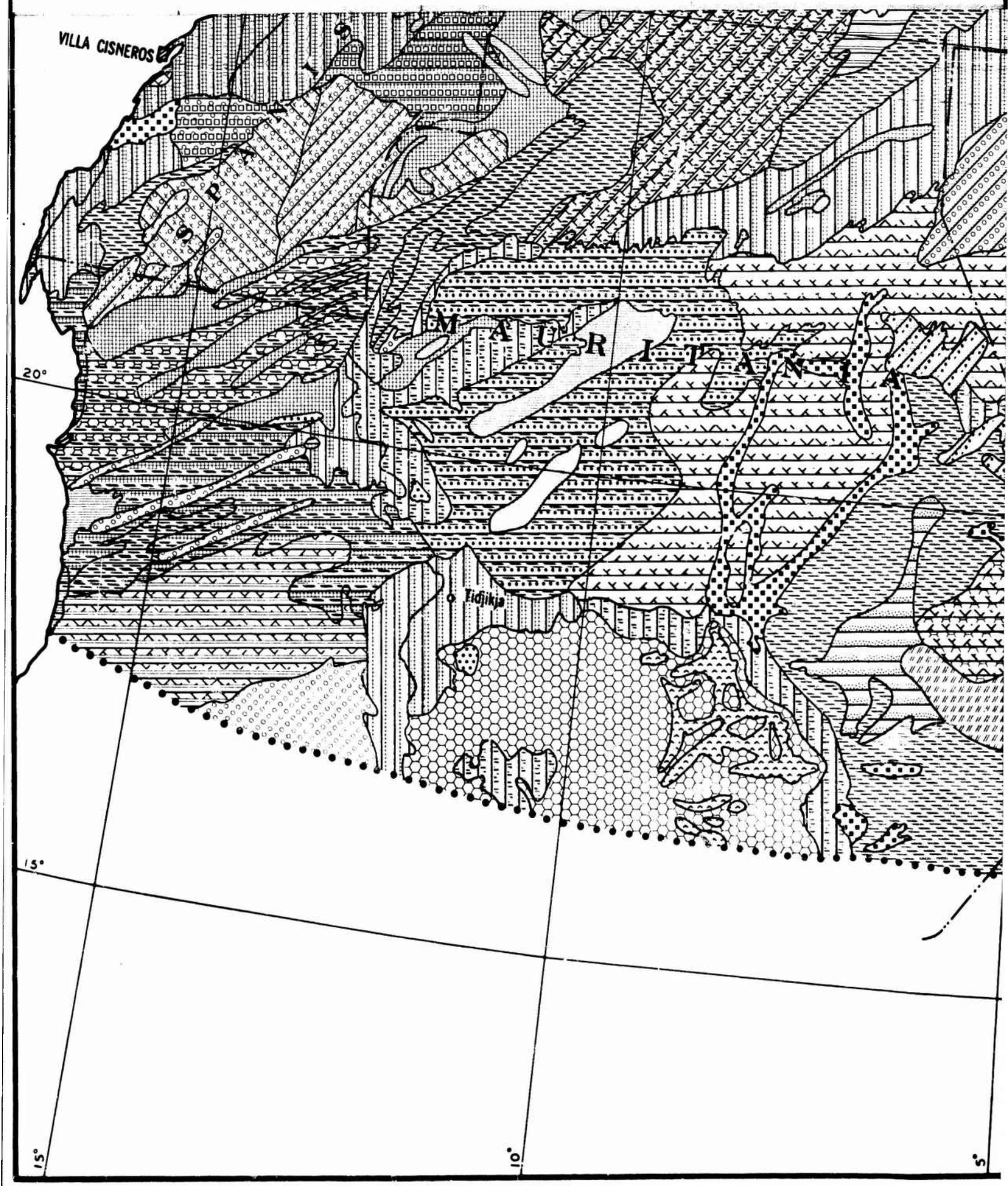
5 10 MI.

YUMA TEST STATION

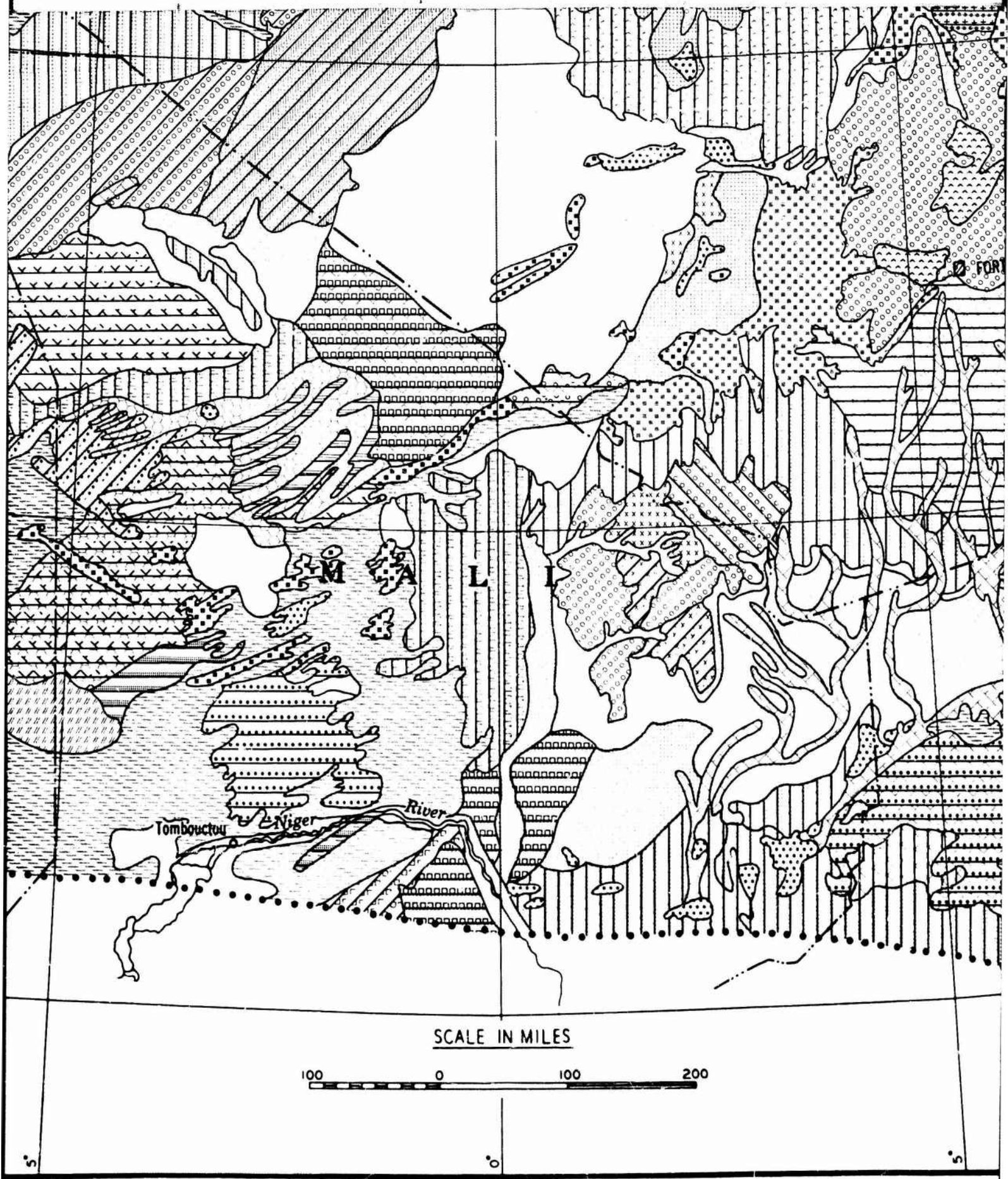
(GROSS LANDSCAPE: 5L//,1,5,7)

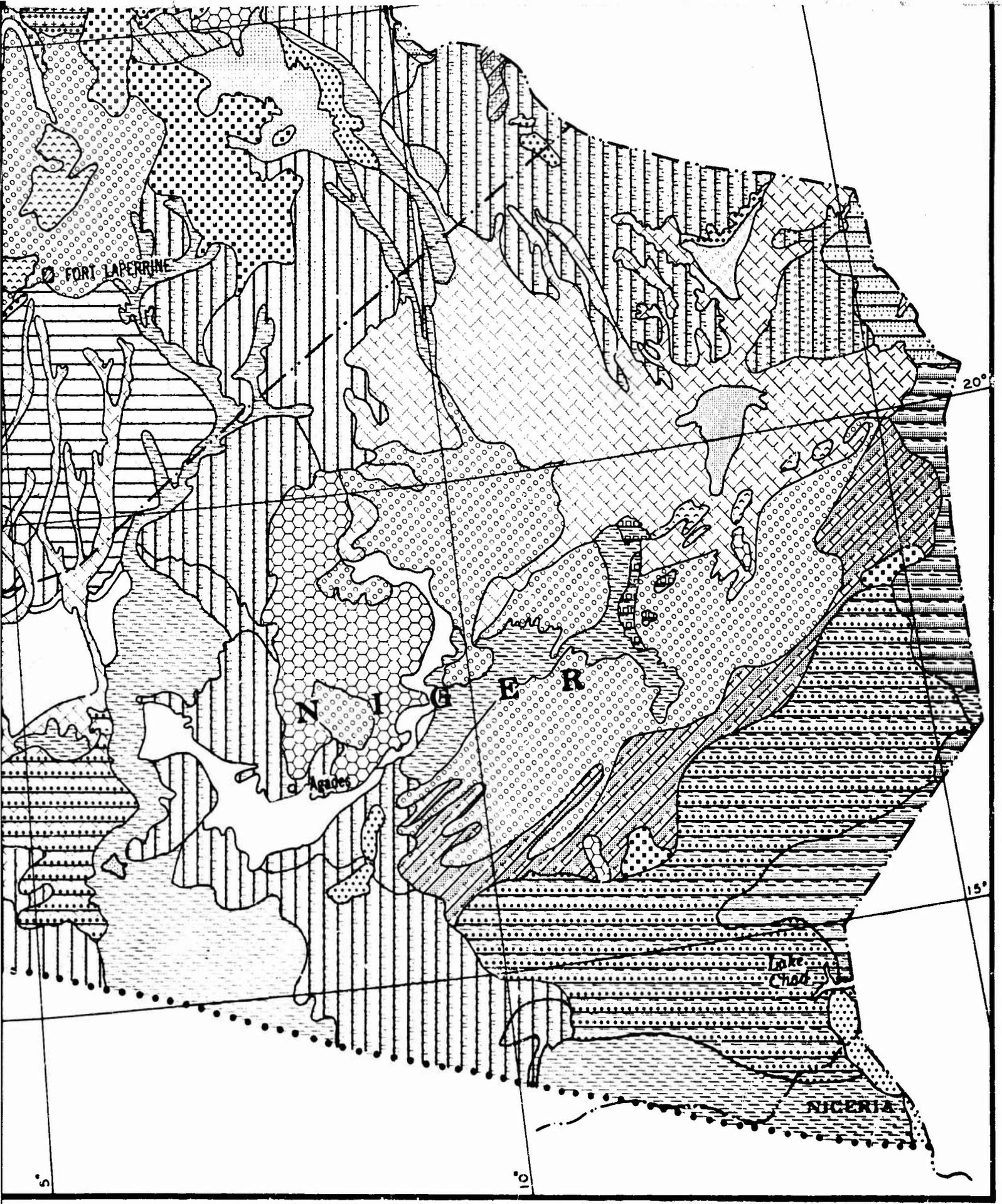
GENERALIZED LANDSCAPE





5


M A L I
Tombouctou
Niger River
SCALE IN MILES
100 0 100 200
5°
0°
5°



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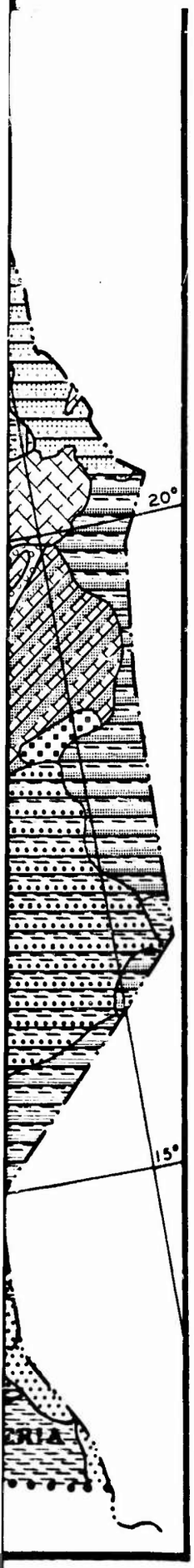
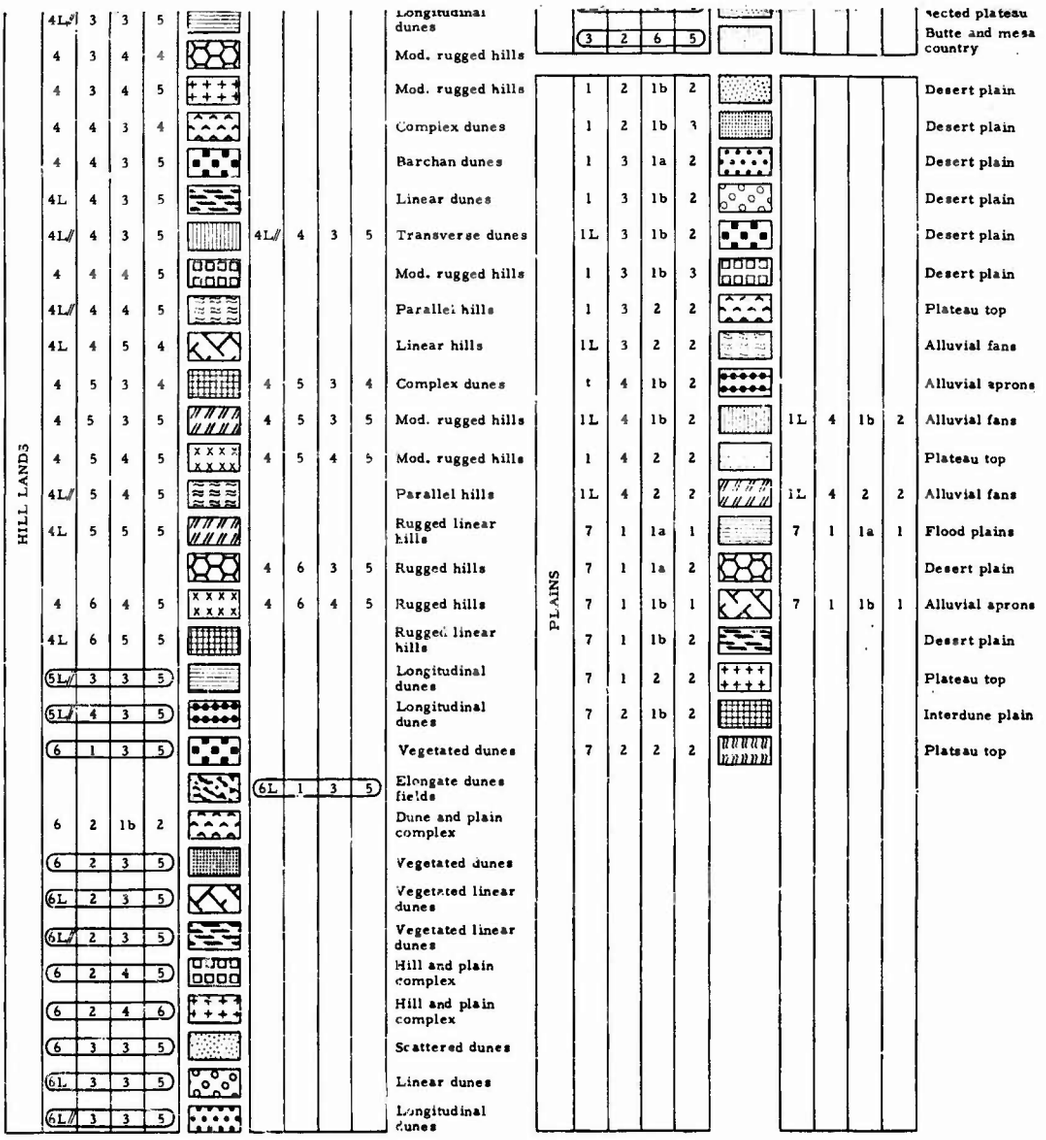
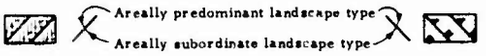




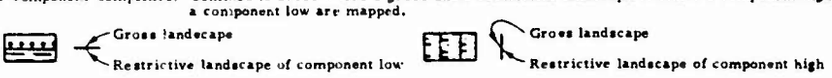
LANDSCAPE COMPLEXES

Areal Complexes: Areas where two major, areally restricted landscape types, both of the restrictive type, occur.



Slope of fraction line depends on type of complex found in plan-profile.

Gross-component Complexes: Confined to areas where a gross and a restrictive landscape of either a component high or a component low are mapped.



* Each landscape type in the legend is identified by a series or an array of four symbols indicating mapping units of plan-profile (PP), slope occurrence (SO), characteristic slope (CS), and characteristic relief (CR), always designated in that order.

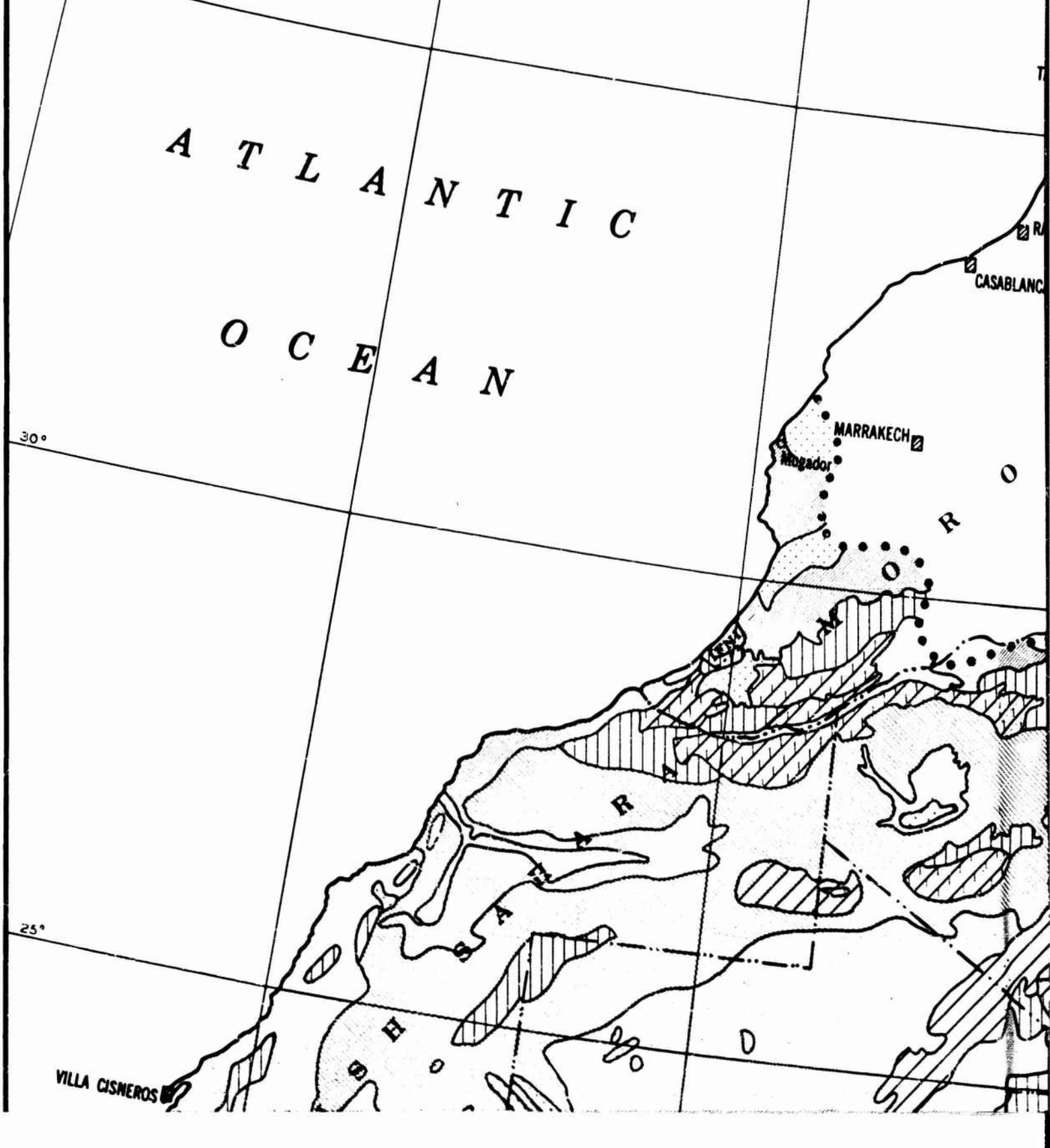
† A circled series of numbers identifies a gross landscape type.

** Major groupings of generalized landscapes are based on physiography for convenience only. It should be realized that surface geometry is often entirely independent of physiographic association.

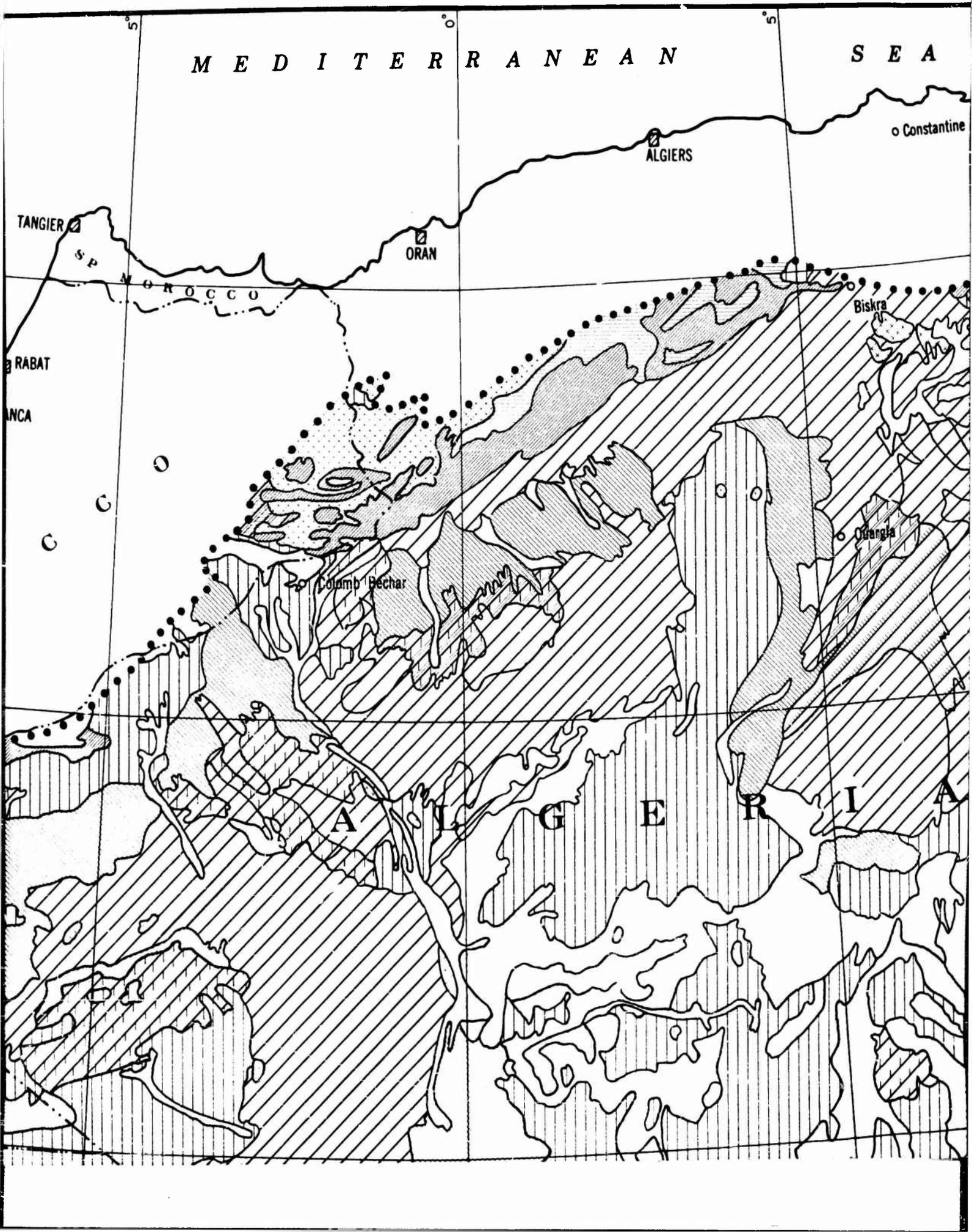
ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT
GENERALIZED LANDSCAPE

PLATE 5

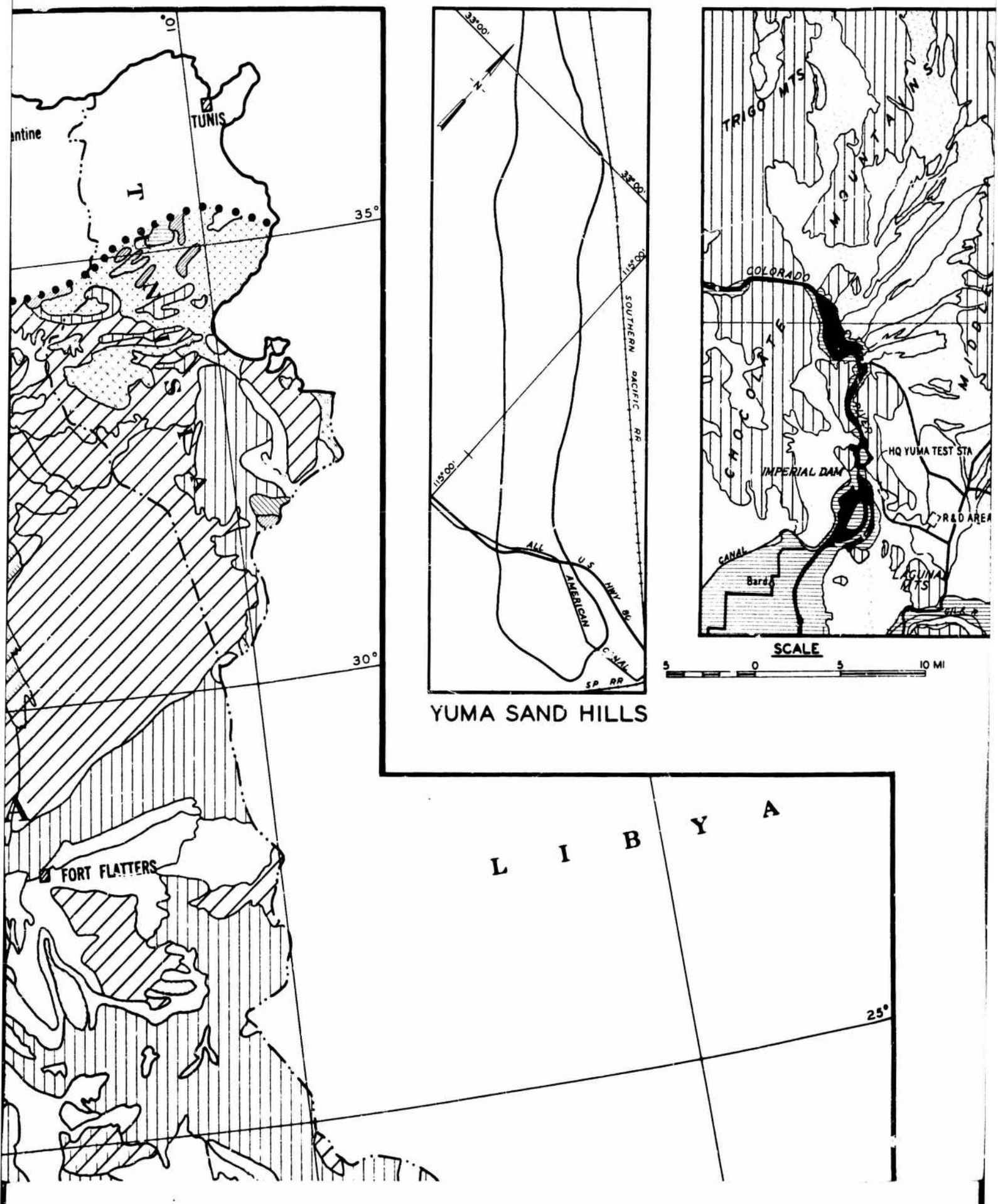
8


20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
CASABLANC
MARRAKECH
Mogador
MOROCCO
SAHARA
VILLA CISNEROS

2

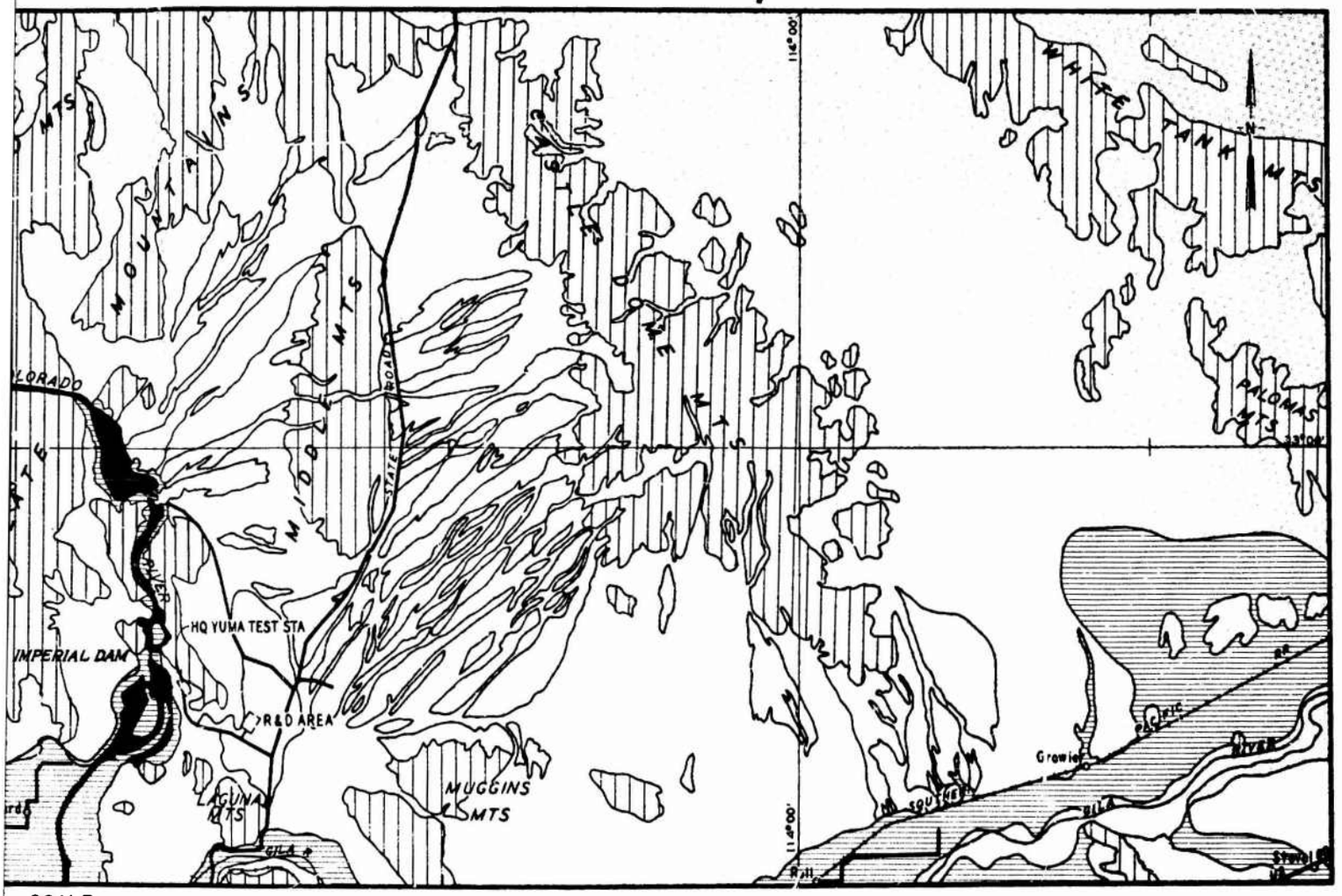

MEDITERRANEAN SEA
ALGIERS
Constantine
TANGIER
ORAN
SP
MOROCCO
RABAT
Biskra
Colomb Bechar
Ouargla
ALGERIA

3



YUMA SAND HILLS

4



SCALE

0 5 10 MI

YUMA TEST STATION

A

25°

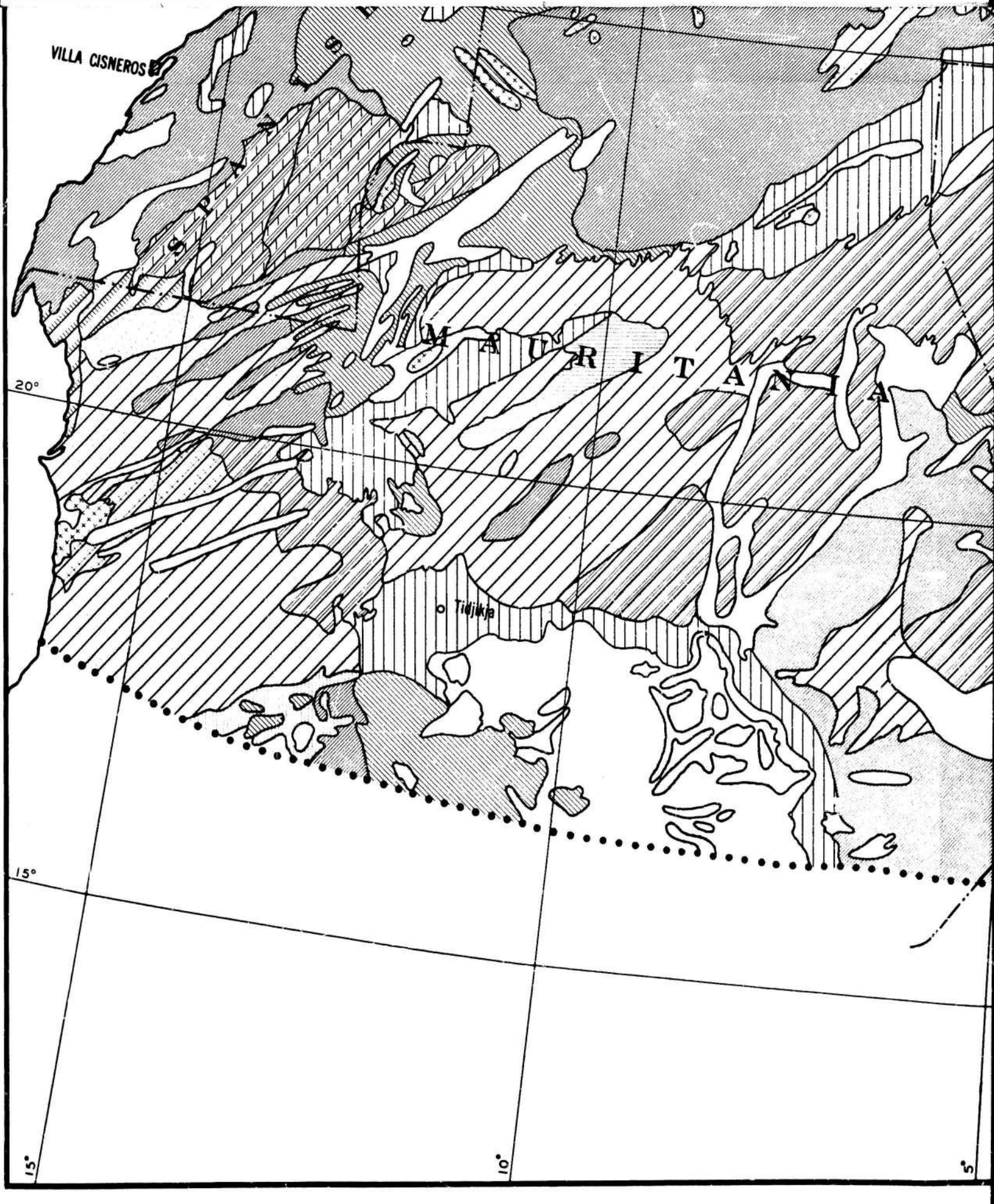
SOIL TYPE

I. SOIL-ROCK ASSOCIATIONS

1 Areas characterized by a mosaic of bare rock and stony soils* with a few scattered patches of coarse and fine-grained soils. Bare rock and stony soils cover more than 90 per cent of the area mapped.

2 Areas characterized by a mosaic of bare rock and stony soils with numerous patches of coarse and fine-grained soils. Bare rock and stony soils cover from 50 to 90 per cent of the area mapped.

3 Areas characterized by a mosaic of coarse and fine-grained soils with numerous rock and stony



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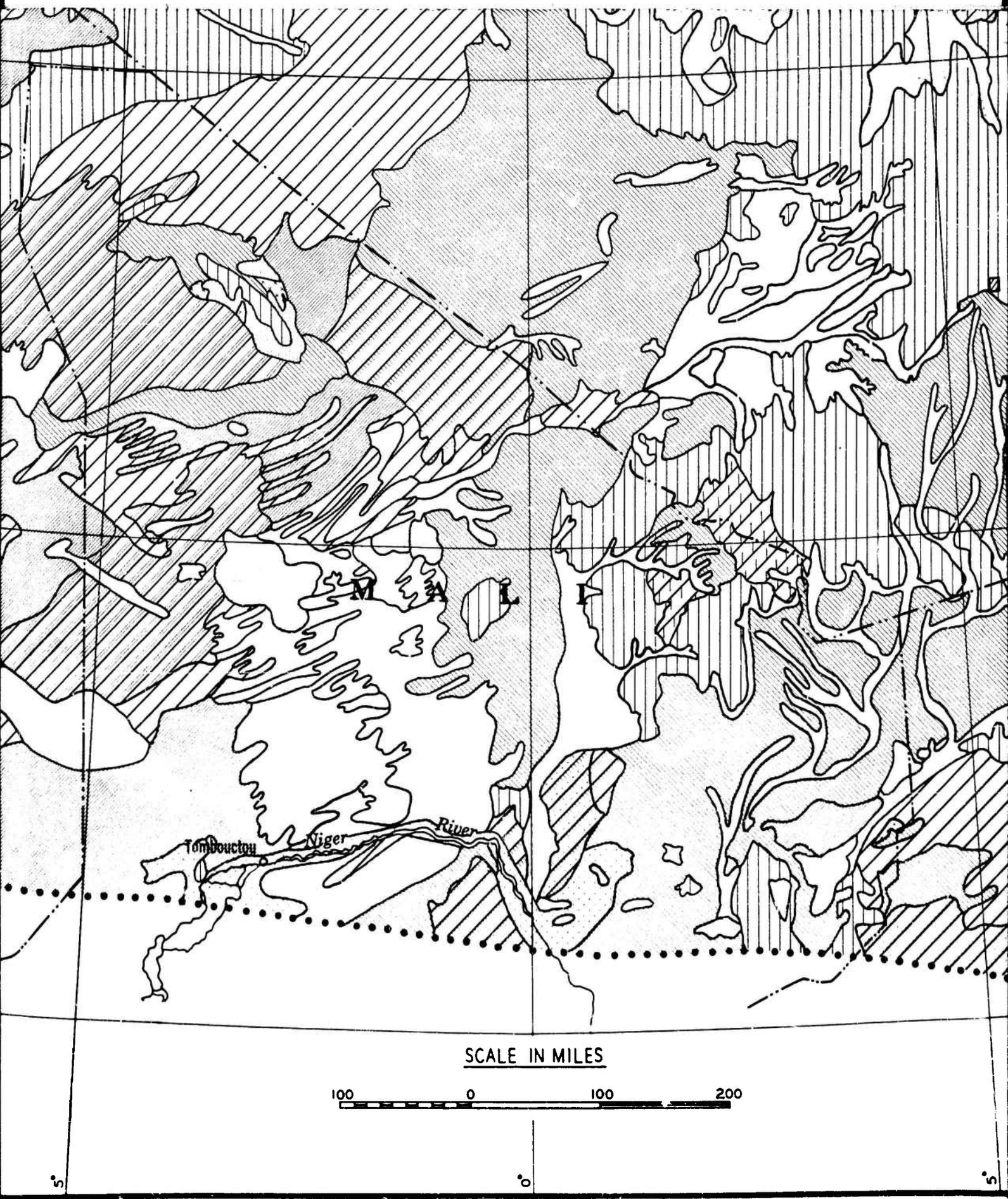
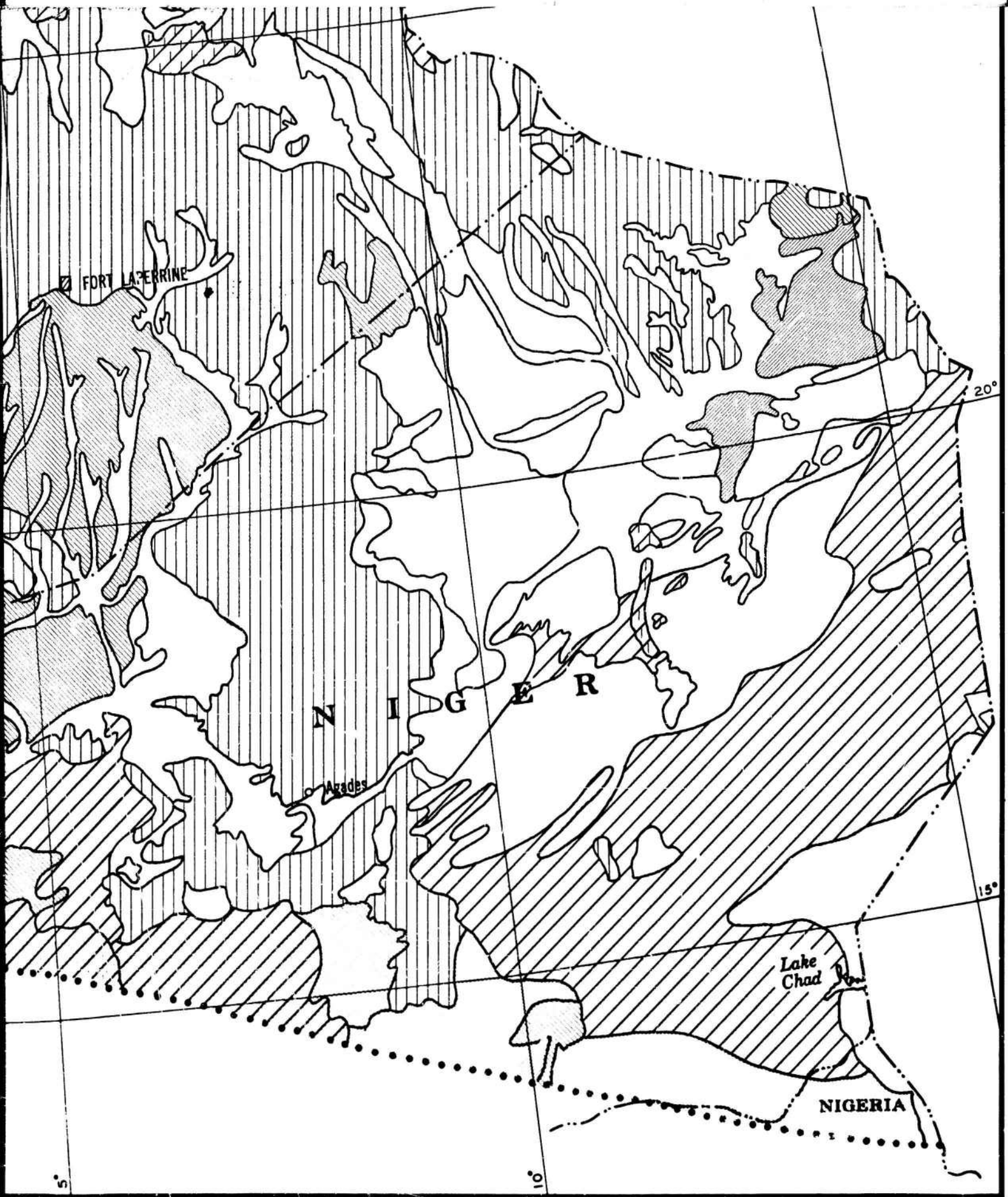
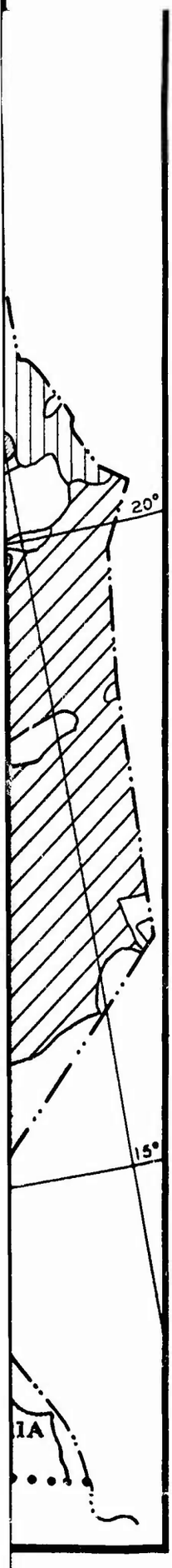

M A L I
Tombouctou
Niger
River
SCALE IN MILES
100 0 100 200
5°
0°
5°


FORT LAMY
FORT LAPERRINE
N I G E R
Agadès
Lake Chad
NIGERIA
20°
15°
5°
10°



2 Areas characterized by a mosaic of bare rock and stony soils with numerous patches of coarse and fine-grained soils. Bare rock and stony soils cover from 50 to 90 per cent of the area mapped.

3 Areas characterized by a mosaic of coarse and fine-grained soils with numerous rock and stony soil outcrops. Bare rock and stony soils cover from 20 to 50 per cent of the area mapped.

Areas where patches of soil consist of unconsolidated deposits of volcanic ash or ejecta.

*Stony soils: More than 75 per cent of a typical sample consists of material coarser than gravel. Coarse-grained soils: More than 50 per cent of a typical sample consists of sand and/or gravel. Fine-grained soils: More than 50 per cent of a typical sample consists of silt and/or clay.

II. SOIL ASSOCIATIONS*

Areally predominant (70 per cent or more) soil type mapped. Area mapped never includes more than 20 per cent bare rock and stony soils.

COARSE-GRAINED SOILS

4 Gravel: More than 90 per cent of a typical sample consists of gravel.

5 Sand: More than 90 per cent of a typical sample consists of sand.

6 Sand and gravel mixed with minor amounts of finer material: More than 50 per cent of a typical sample consists of sand and/or gravel.

FINE-GRAINED SOILS

7 Silt and clay with minor amounts of coarser material: More than 50 per cent of a typical sample consists of silt and/or clay.

8 Silt: More than 75 per cent of a typical sample consists of silt.

9 Clay: More than 75 per cent of a typical sample consists of clay.

10 Saline: A typical soil sample has a salt content of more than 25 per cent—usually associated with silt and clay.

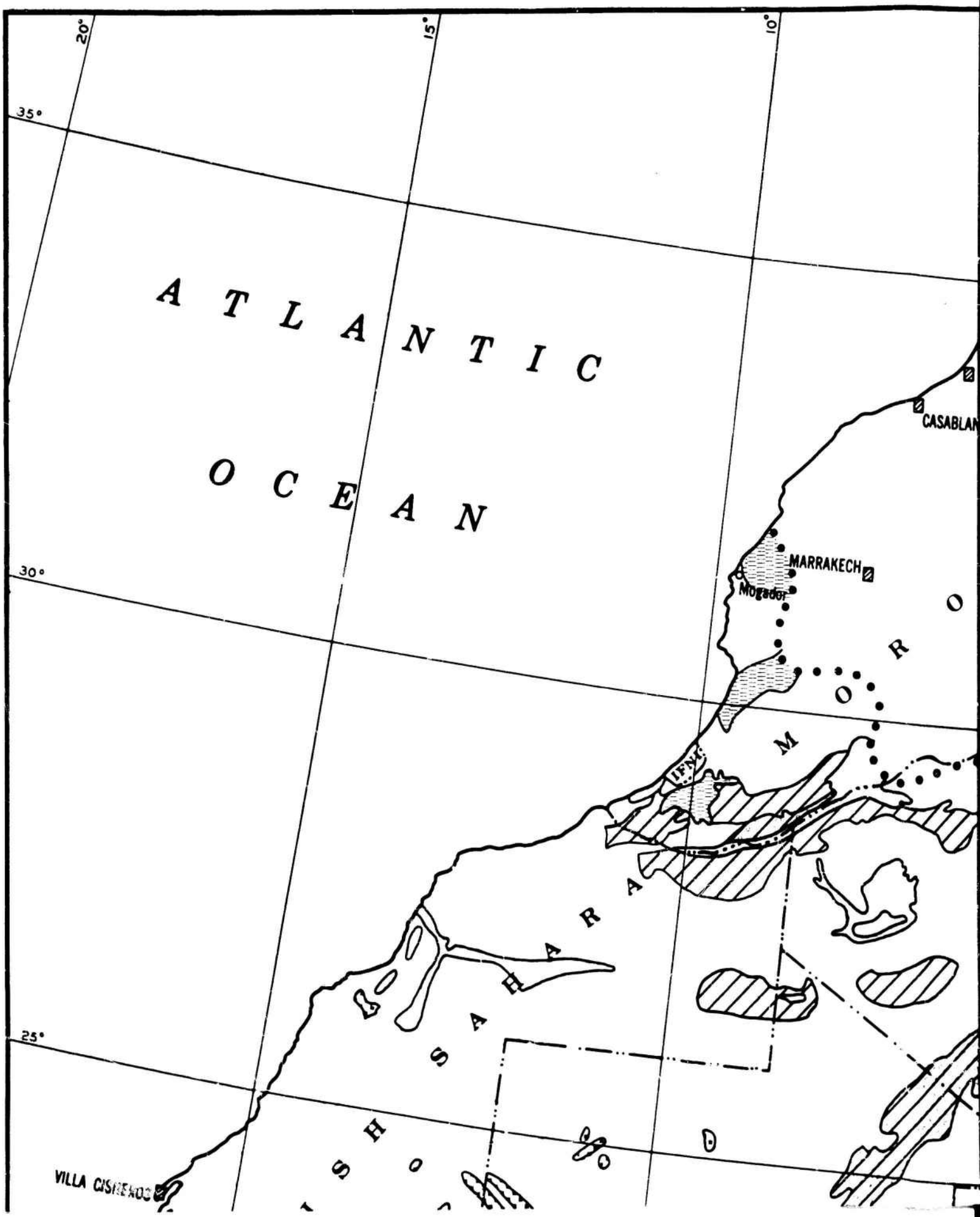
5/4 SOIL COMPLEXES: Soil complexes are mapped where no areally predominant (70 per cent or more) soil type occurs. In such instances, the two most commonly occurring soil types are mapped; the predominant is shown as the numerator, the subordinate as the denominator in the fractional pattern.

* In general soil association exhibits soil thickness greater than 10 feet.

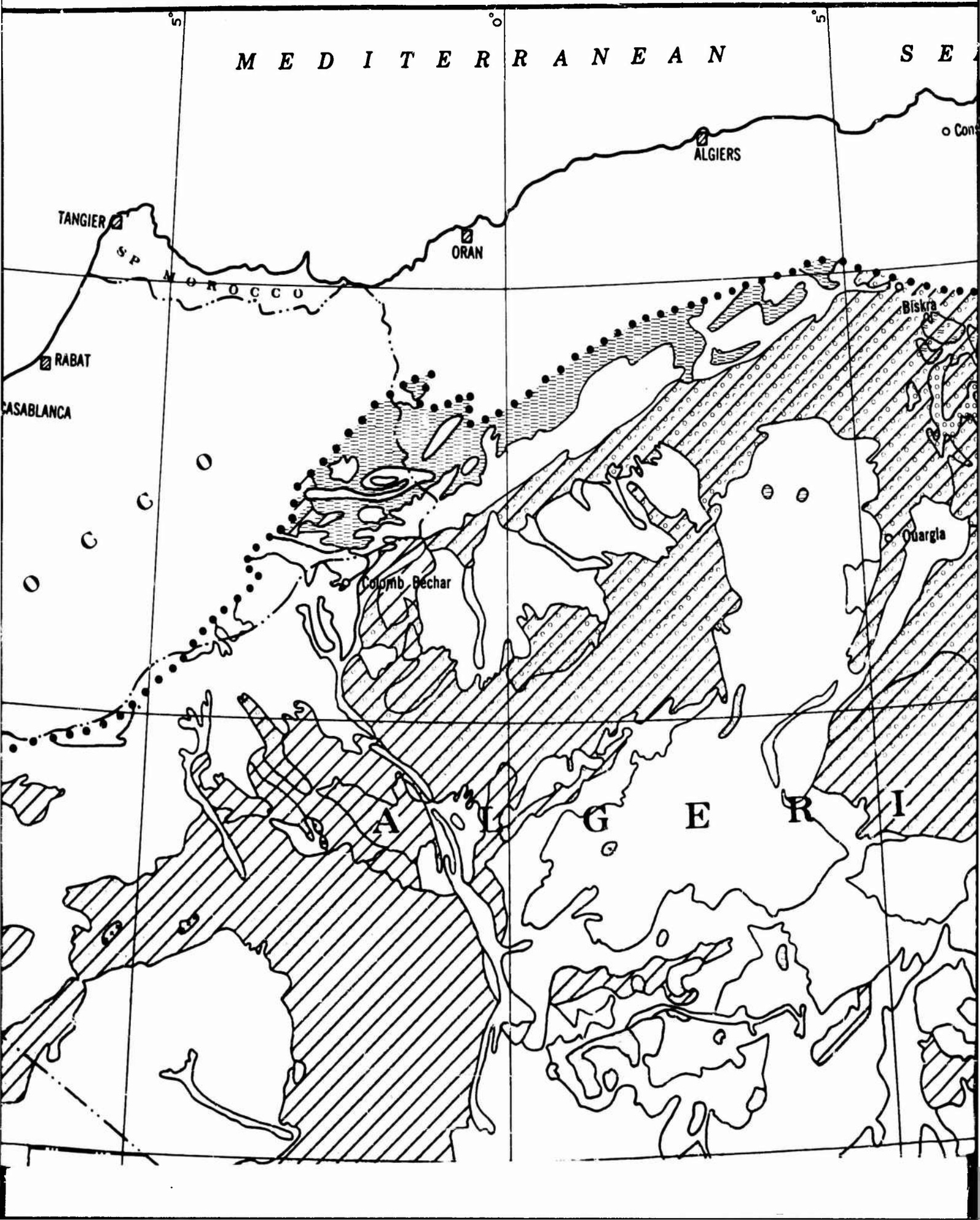
ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

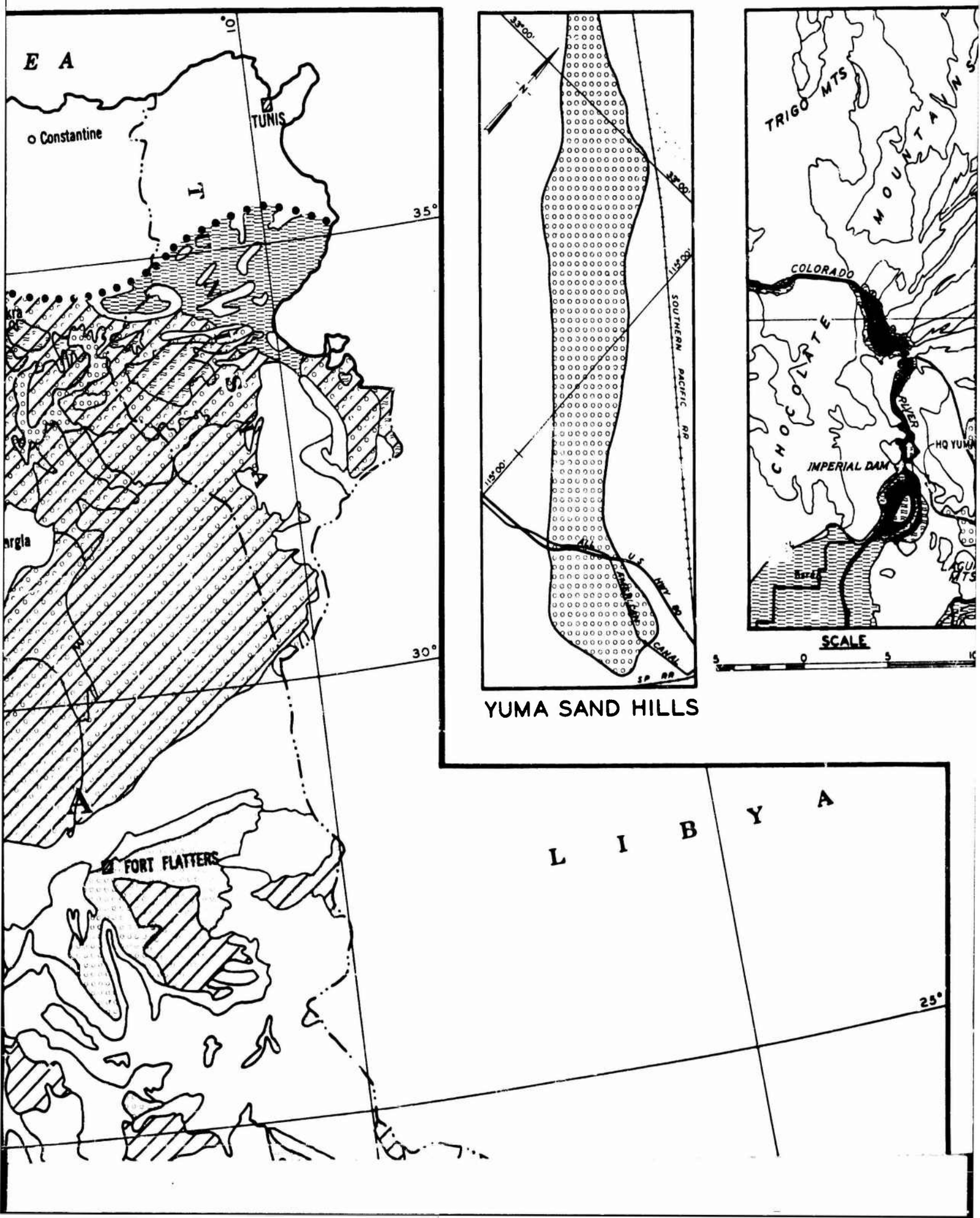
SOIL TYPE

PLATE 6

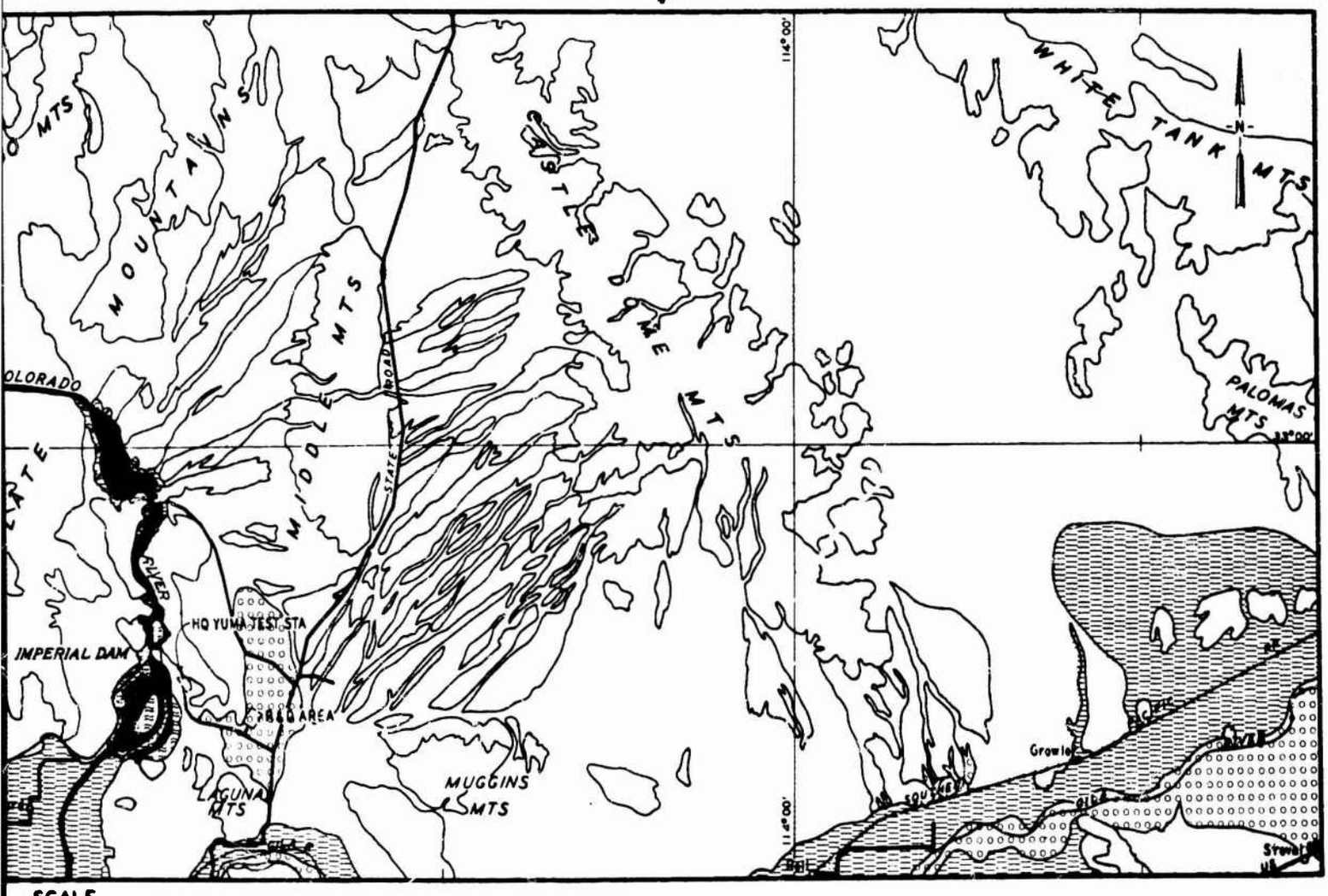

20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
CASABLAN
MARRAKECH
Mogador
MOROCCO
IFNI
SAHARA
SPANISH
VILLA CISNEROS

2


5°
0°
5°
MEDITERRANEAN
SE
ALGIERS
TANGIER
ORAN
SP
MOROCCO
RABAT
CASABLANCA
Biskra
Ouargla
Colomb Bechar
ALGERI


E A
TUNIS
Constantine
35°
30°
FORT FLATTERS
L I B Y A
25°
33°00'
115°00'
SOUTHERN PACIFIC RR
U.S. HWY 80
CANAL
SP RR
YUMA SAND HILLS
TRIGO MTS
MOUNTAINS
COLORADO
CHOCOLATE
RIVER
IMPERIAL DAM
HQ YUMA
SCALE

4



YUMA TEST STATION

A

25°

SOIL CONSISTENCY

Soil consistencies are mapped only where soil associations occur. Areally predominant (70 per cent or more) soil consistency mapped.

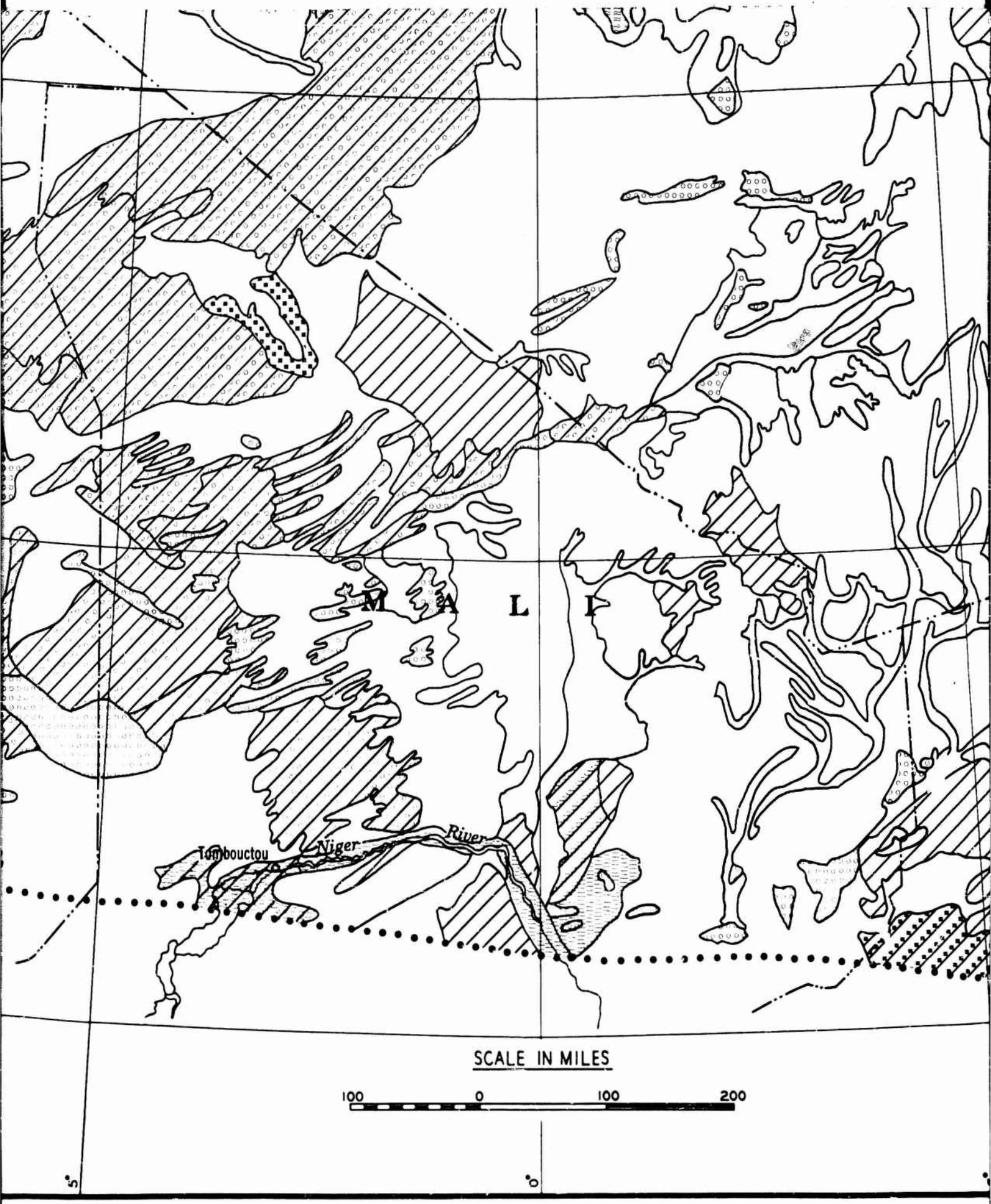
I. HOMOGENEOUS CONSISTENCIES: Soils of essentially unchanged consistencies to depth greater than 12 inches.

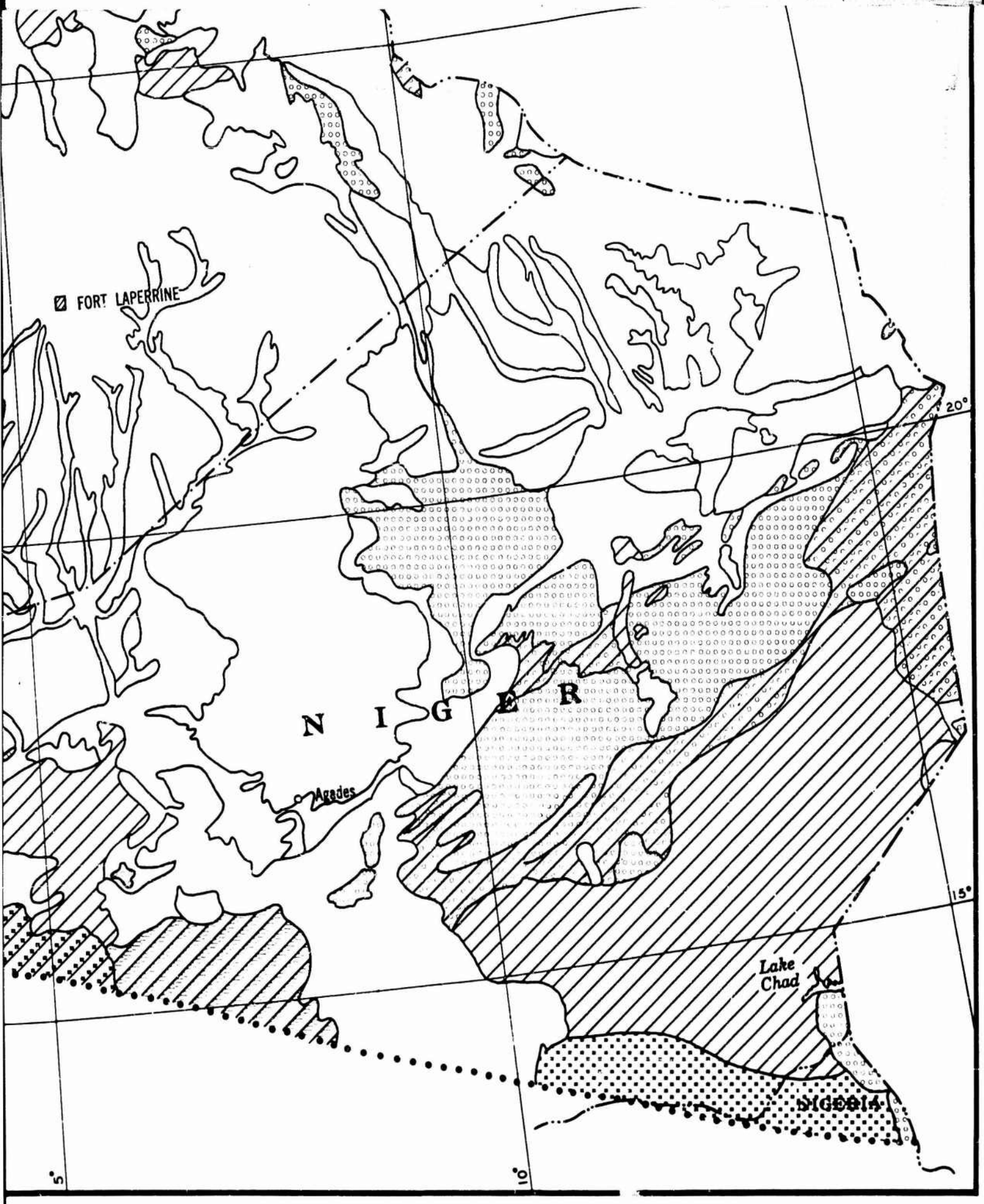
A. Noncohesive: Materials in which the constituent particles do not adhere to each other.

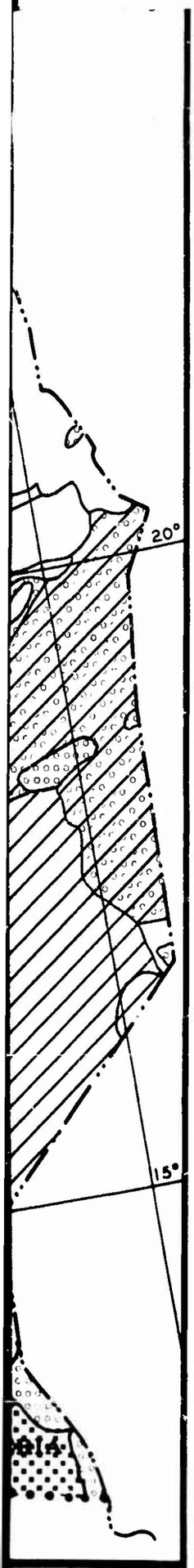
1 Loose: The ratio of voids to constituent grains is close to a naturally occurring maximum, i.e., the grains are loosely packed.

2 Dense: The ratio of voids to constituent particles is close to a naturally occurring minimum, i.e., the


VILLA CISNEROS
SPANISH
MAURITANIA
Tidjikja
20°
15°
15°
10°
5°


M A L I
Tombouctou
Niger
River
SCALE IN MILES
100
0
100
200
5°
0°


FORT LAPERRINE
N I G E R
Agades
Lake Chad
NIGERIA
20°
15°
10°
5°



1 Loose: The ratio of voids to constituent grains is close to a naturally occurring maximum, i.e., the grains are loosely packed.

2 Dense: The ratio of voids to constituent particles is close to a naturally occurring minimum, i.e., the grains are closely packed.

B. Cohesive: Materials in which the constituent particles adhere to each other, either because of mutual attraction of the particles themselves, or because of the presence of a cementing material.

3 Soft (usually perennially wet): Little or no bearing capacity.

4 Firm: Moderate bearing capacity.

5 Hard: High bearing capacity.

II. LAYERED CONSISTENCIES: Soils possessing two or more relatively discrete layers within 12 inches of the surface.

A. Crusted Surfaces: Surface crust may be either cohesive or noncohesive.

6 Hard thin crust (commonly of cemented materials) overlying soft materials (commonly muck, ooze, or saturated silts).

7 Hard crust (commonly of cemented materials) overlying noncohesive material (commonly sand or silt).

8 Thin zone of firm materials over noncohesive materials. (Most common development in areas of fixed dunes, with more or less continuous vegetation cover.)

9 Surface of closely-fitted noncohesive pebbles or gravel overlying noncohesive materials (commonly sand or silt). (Such "desert pavements" also occur over bedrock or materials of firm consistencies, but this is less common.)

B. Noncohesive surface layer less than 12 inches thick.

10 Dense layer within 12 inches of the surface.

11 Hard layer within 12 inches of the surface (usually but not always caliche).

3/4 CONSISTENCY COMPLEXES: Consistency complexes are mapped where no areally predominant (70 per cent or more) consistency occurs. In such instances, the two most commonly occurring consistencies are mapped; the predominant is shown as the numerator, the subordinate as the denominator in the fractional pattern.

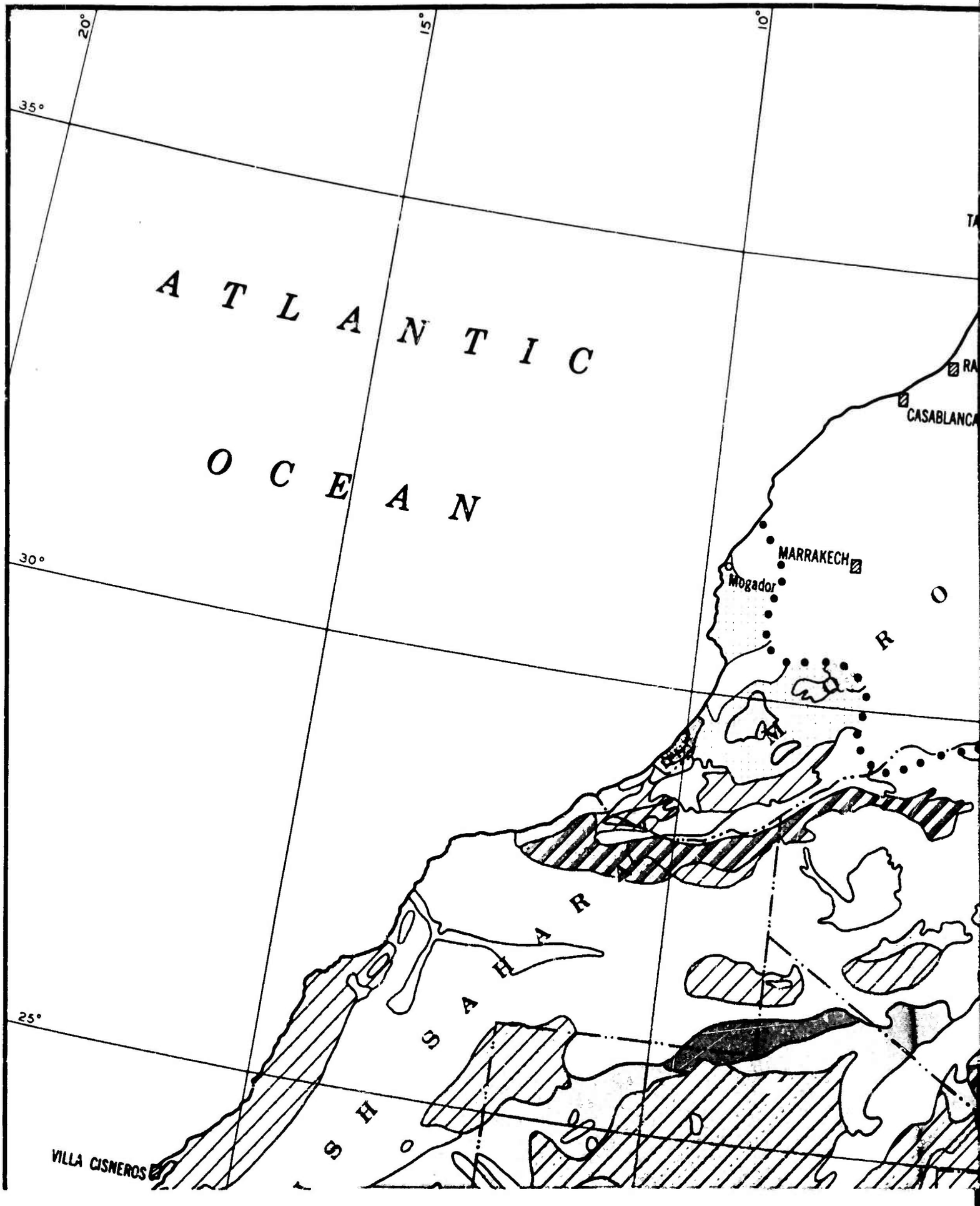
In complexes (e.g., 3/4) the first digit always refers to the areally predominant unit.

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

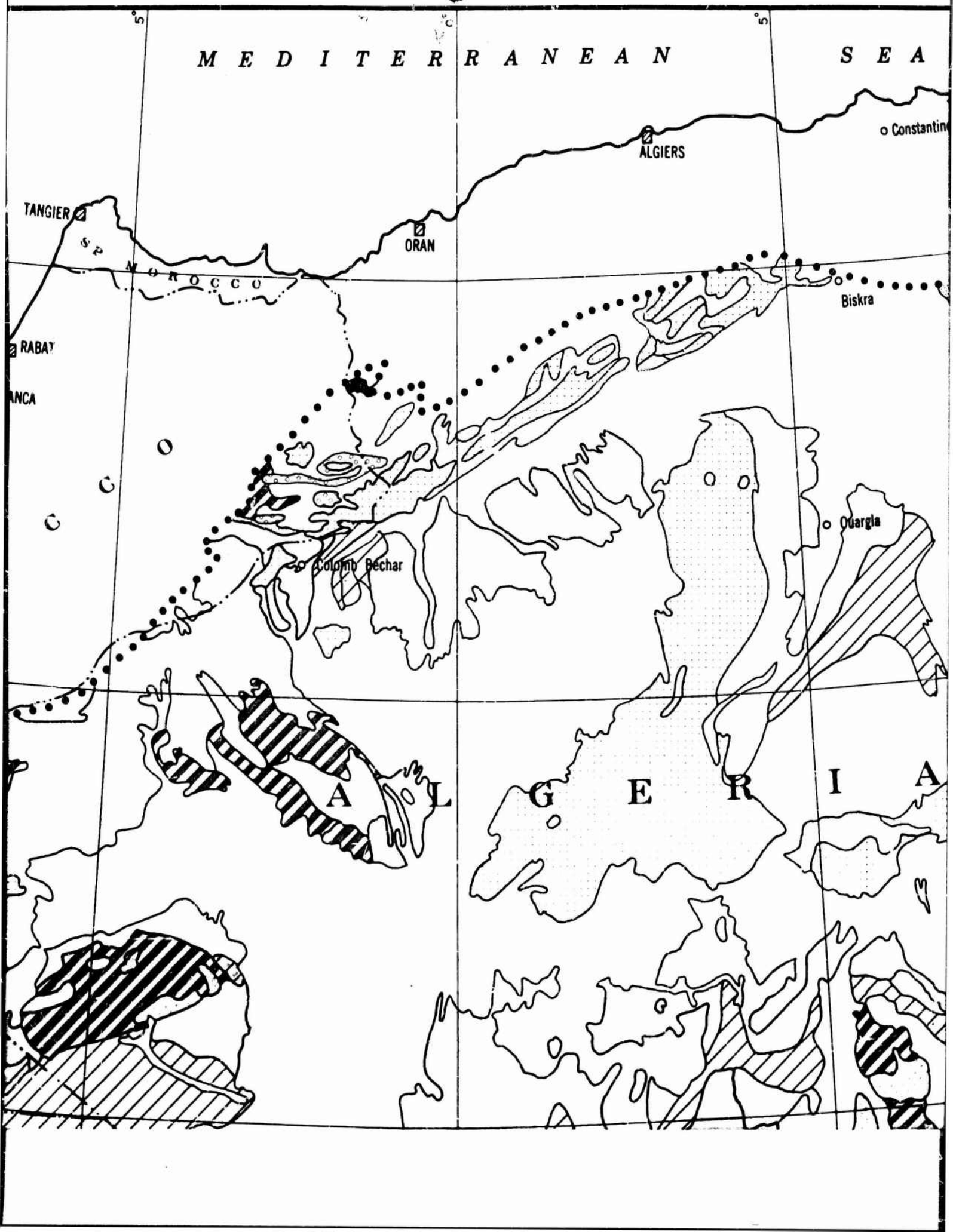
SOIL CONSISTENCY

PLATE 7

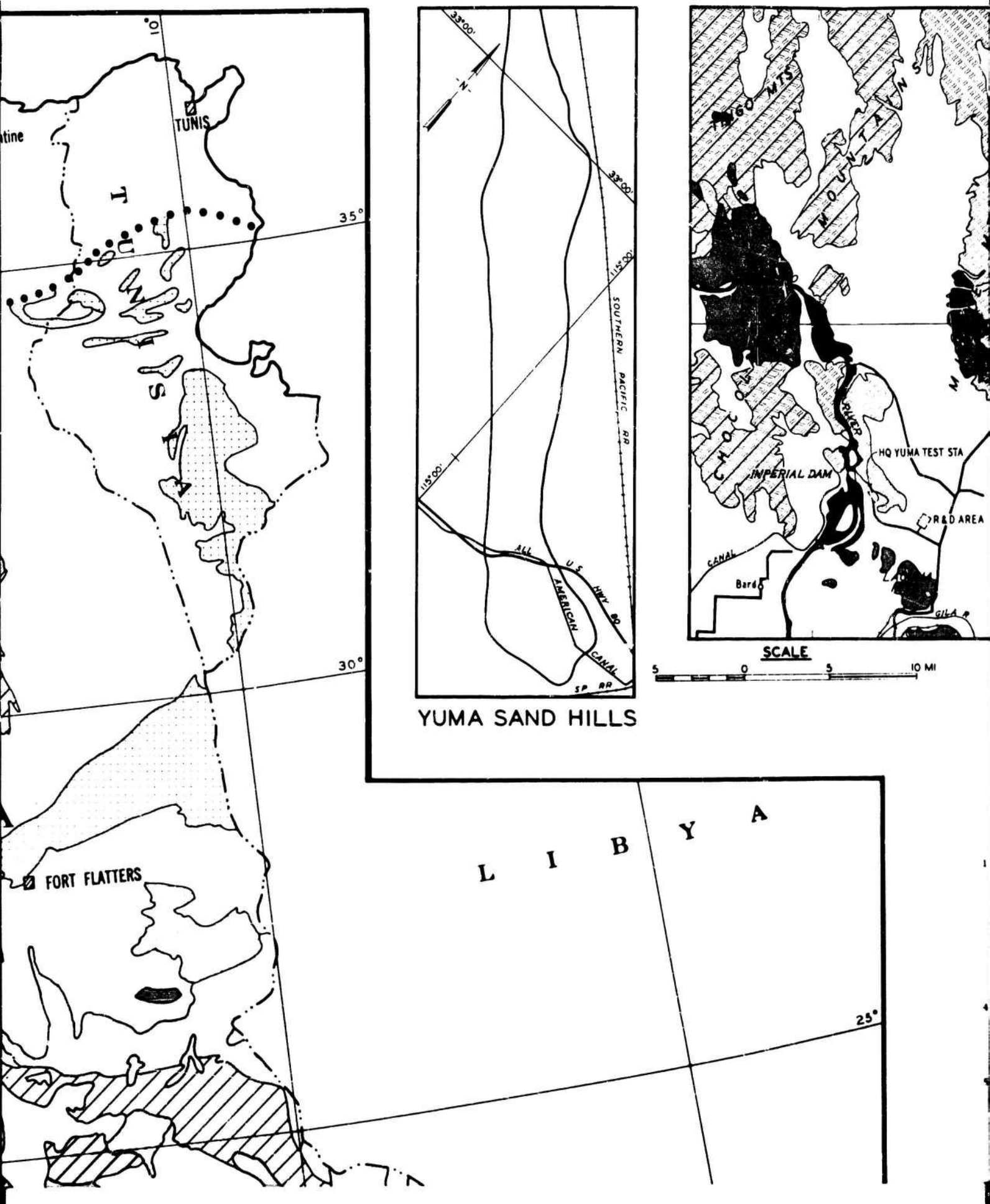
8


20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
MARRAKECH
Mogador
CASABLANCA
SHARO
VILLA CISNEROS

2

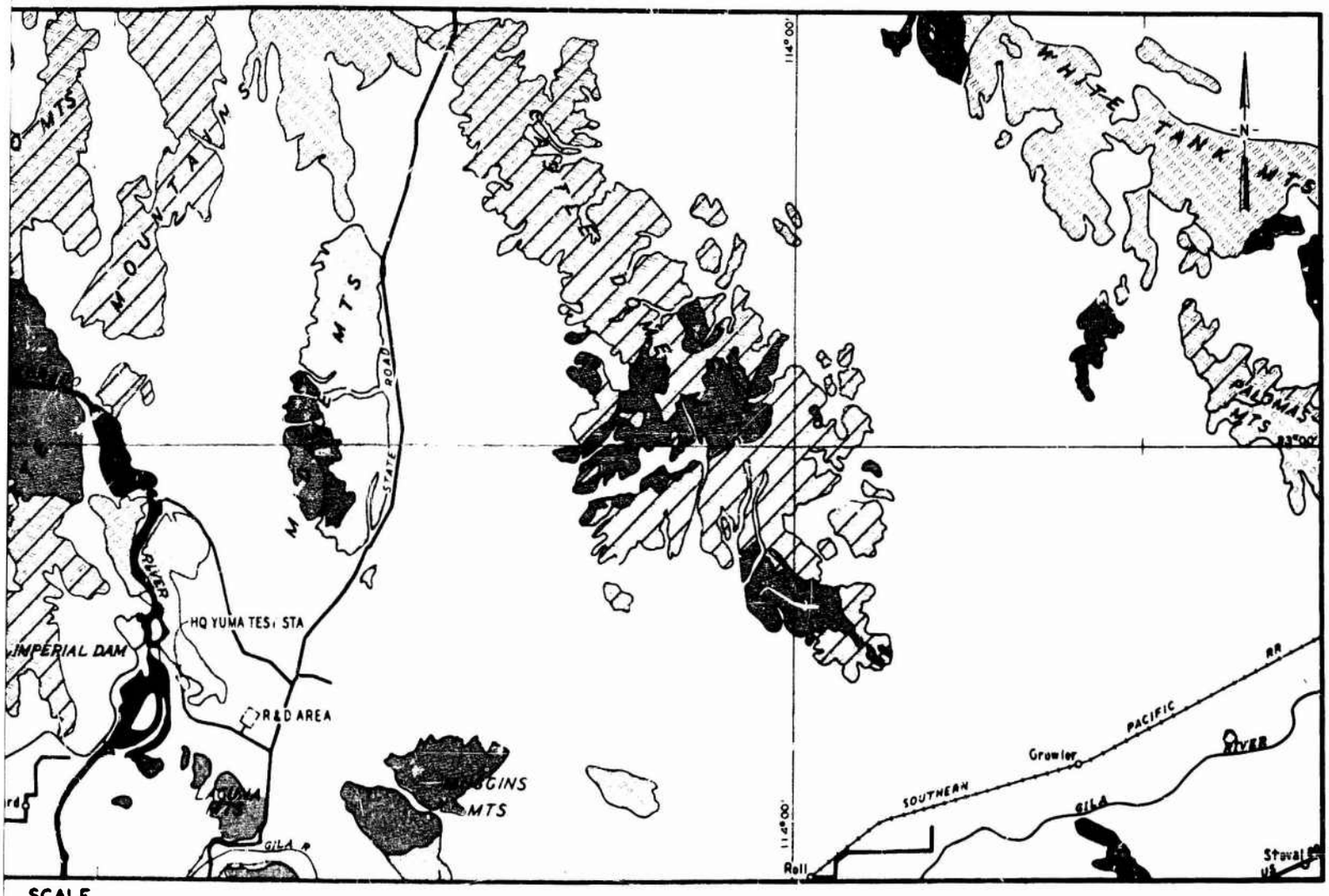

MEDITERRANEAN SEA
ALGIERS
Constantine
TANGIER
ORAN
SP. MOROCCO
Biskra
RABAT
CASABLANCA
Colomb Bechar
Ouargla
ALGERIA

3



YUMA SAND HILLS

4



YUMA TEST STATION

A

25°

SURFACE ROCK

Mapped in regions where rock is exposed and at shallow depths (i.e. 0-10 feet)* throughout the remainder of the area. In effect this procedure restricts the mapping of surface rock to areas mapped as 1, 2, or 3 under Soil Type.

Areally predominant (70 percent or more) rock type mapped.

1 **IGNEOUS (UNDIFFERENTIATED):** Rocks formed by solidification or crystallization of a hot fluid mass.

2 **Intrusive:** Igneous rocks, typically crystalline, which have formed by cooling below the surface of the earth (granite, syenite, diorite, etc.).

3 **Extrusive (undifferentiated):** Igneous rocks which have formed by cooling at the surface of the earth.

3a True extrusive rocks formed by solidification of molten material that poured out on the surface of the earth (e.g. basalt, dacite, etc.).

3b Rocks formed by secondary cementation of loose deposits of volcanic ejecta (e.g. tuff, agglomerate, etc.).

4 **METAMORPHIC (UNDIFFERENTIATED):** Rocks formed from original igneous or sedimentary rocks through alterations produced by pressure, heat, or the infiltration of other materials at depths below the surface zones of weathering and cementation. The alterations are sufficiently complete throughout the body of the rock to produce a well-defined new type (gneiss, schist, slate, etc.).

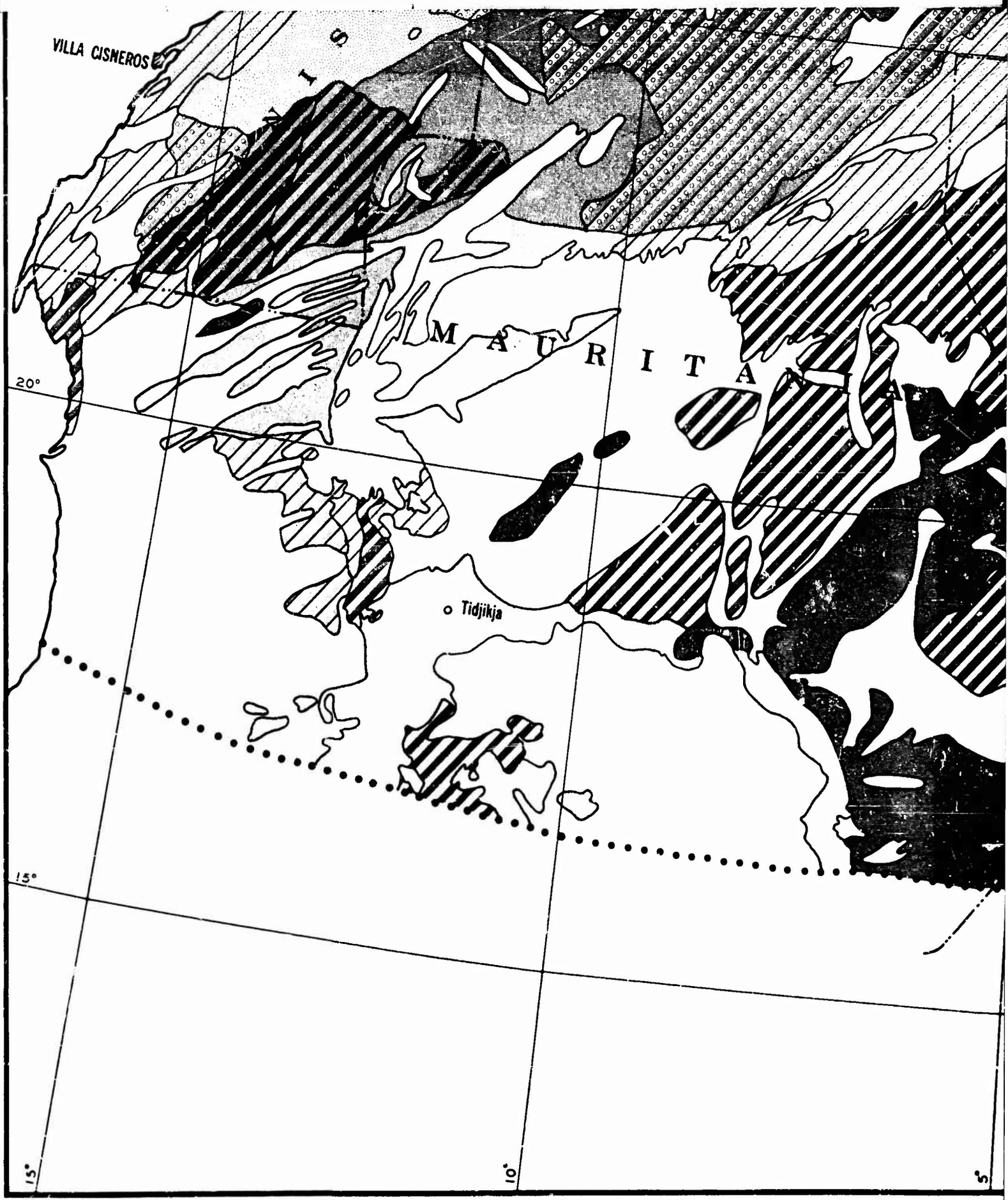
5 **SEDIMENTARY (UNDIFFERENTIATED):** Rocks formed from material laid down in a more or less finely divided state, as sediment, through the agency of water, wind, or glaciers.

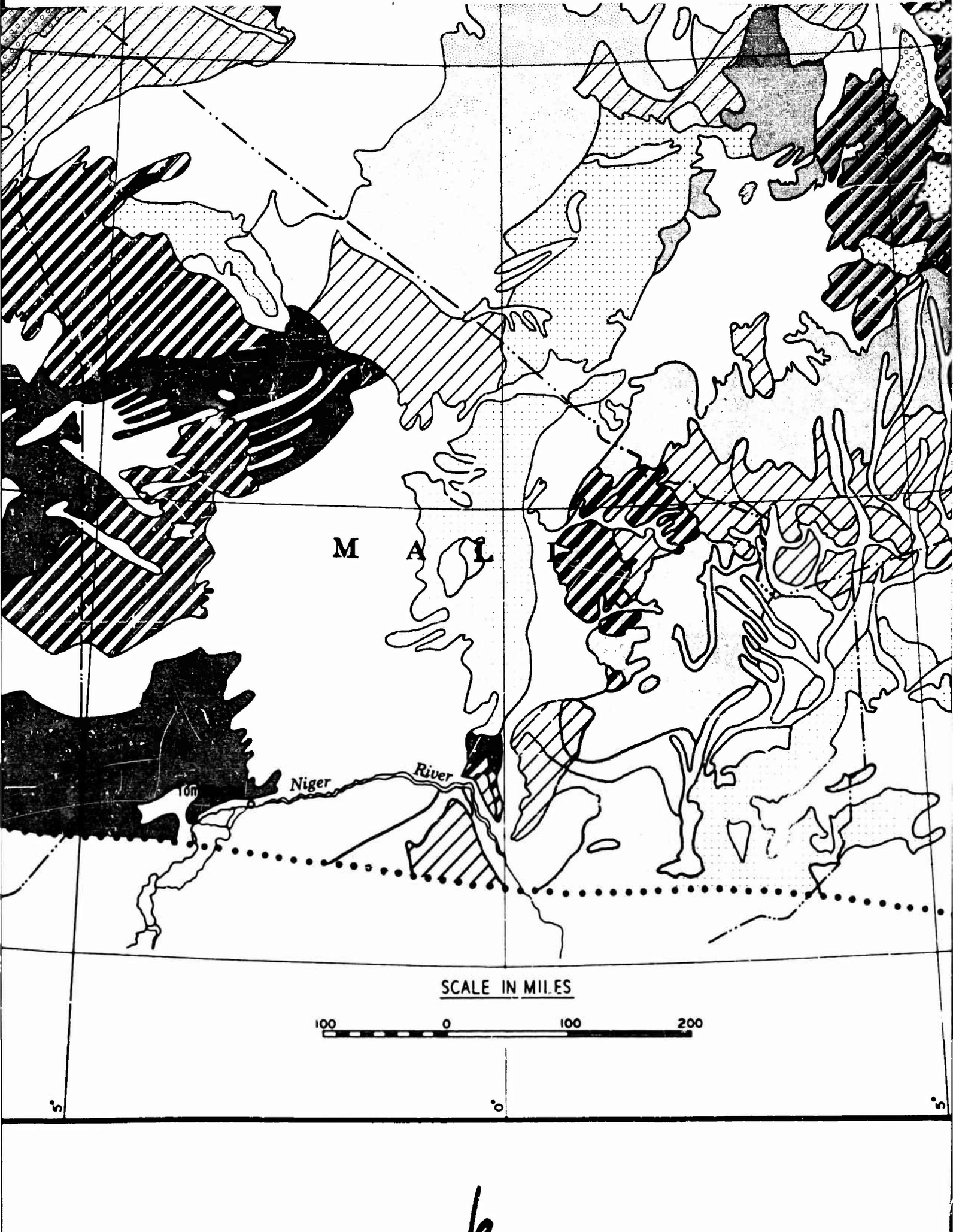
6 **Sandstone:** A sedimentary rock predominantly composed of sand grains cemented together.

7 **Limestone:** A sedimentary rock consisting essentially of calcium carbonate.

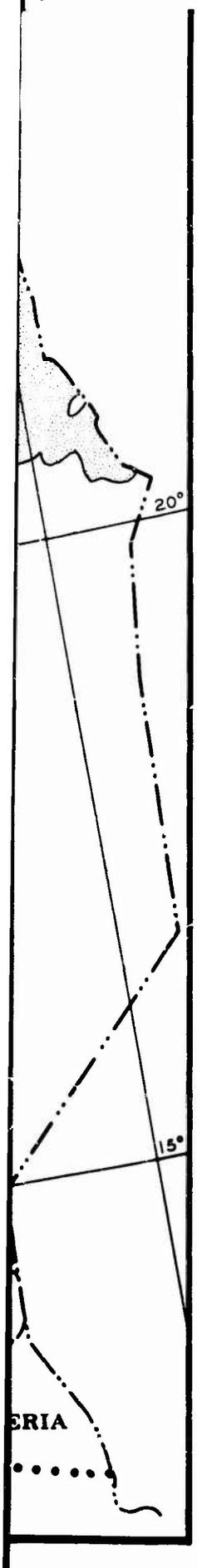
8 **Shale:** A sedimentary rock in which the constituent particles are predominantly of clay size.

9 **Evaporites:** A sedimentary rock whose origin is largely due to evaporation and subsequent


VILLA CISNEROS
I S O
M A U R I T A
20°
Tidjikja
15°
15°
10°
5°


M A L I
Niger River
Tom
SCALE IN MILES
100 0 100 200
5° 0° 5°


20°
15°
N I G E R
Lake
Chad
NIGERIA
5°
10°



7 Limestone: A sedimentary rock consisting essentially of calcium carbonate.

8 Shale: A sedimentary rock in which the constituent particles are predominantly of clay size.

9 Evaporites: A sedimentary rock whose origin is largely due to evaporation and subsequent precipitation of salt from water. (Gypsum, anhydrite, and rock salt are the only evaporites of quantitative importance.)

3a/3b ROCK COMPLEXES: Rock complexes are mapped where no areally predominant (70 percent or more) rock type occurs. In such instances, the two most commonly occurring rock types are mapped; the predominant is shown as the numerator, the subordinate as the denominator in the fractional pattern.

* It should be realized that the scale of mapping precludes delineation, especially in mountainous regions, of many alluvial basins where the thickness of soil cover is much greater than 10 feet.

GENERALIZED ROCK PROPERTIES

Rock Type	RATINGS OF WORKING CHARACTERISTICS																								
	Abrasiveness					Excavational Requirements					Permeability					Stability in Steep-Walled Cuts					Roof Strength in Tunnels					Loading Capacity				
	A	B	C	D	E	a	b	c	d	e	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1. IGNEOUS																									
2. Intrusive																									
3. Extrusive																									
3a. Solidified																									
3b. Cemented																									
4. METAMORPHIC																									
5. SEDIMENTARY																									
6. Sandstone																									
7. Limestone																									
8. Shale																									
9. Evaporites																									

Rock Type	SUITABILITY FOR																								
	Compacted Subgrade					Dimension Stone					Road Metal					Bituminous Aggregate					Concrete Aggregate					Fill				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1. IGNEOUS																									
2. Intrusive																									
3. Extrusive																									
3a. Solidified																									
3b. Cemented																									
4. METAMORPHIC																									
5. SEDIMENTARY																									
6. Sandstone																									
7. Limestone																									
8. Shale																									
9. Evaporites																									

Modified from von Bulow, Kurd, Wehrgeologie Quelle and Meyer, Leipzig. 1938.

Abrasiveness (as it affects excavation tools and equipment):
A. Extreme
B. Severe
C. Moderate
D. Slight
E. Nominal or none

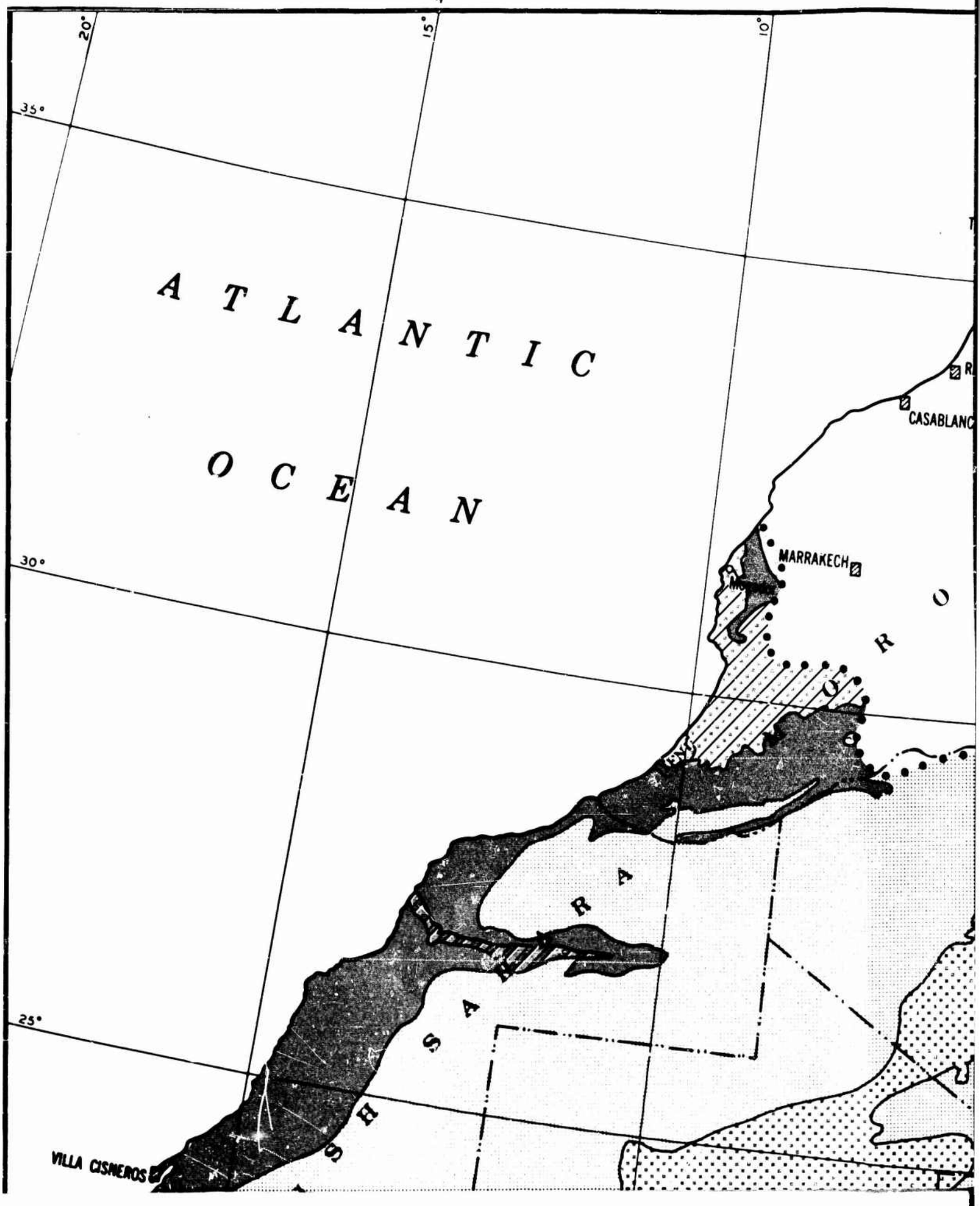
Tools and procedures required to excavate rock:
a. Spade and shovel
b. Pick and shovel
c. Pick, crowbar, and wedge
d. Repeated drilling and blasting
e. Almost continuous drilling and blasting

All other properties:
1. Excellent
2. Good
3. Adequate or fair
4. Poor or usable only in emergencies
5. Inadequate, unsuitable, or absent

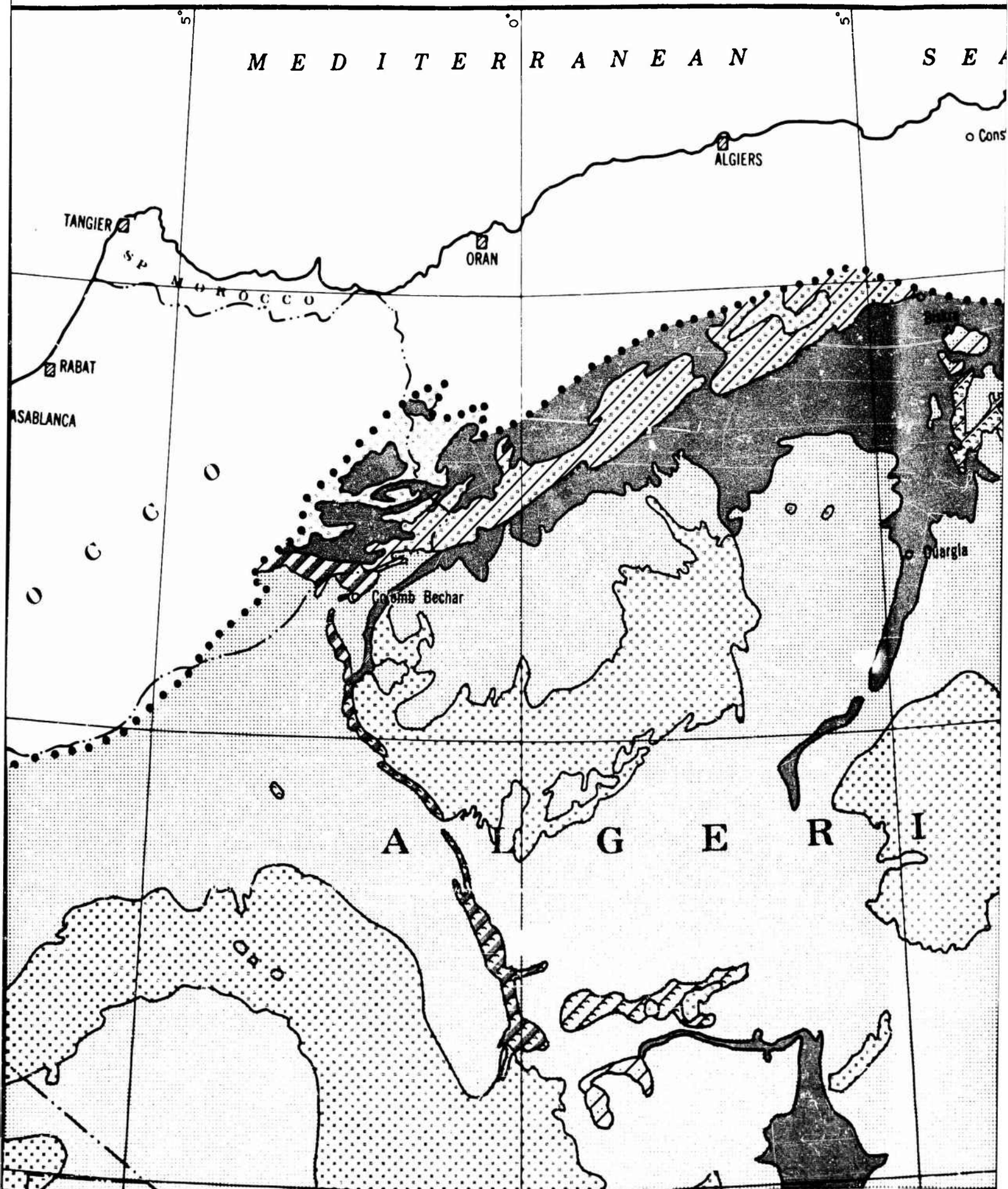
ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT
SURFACE ROCK

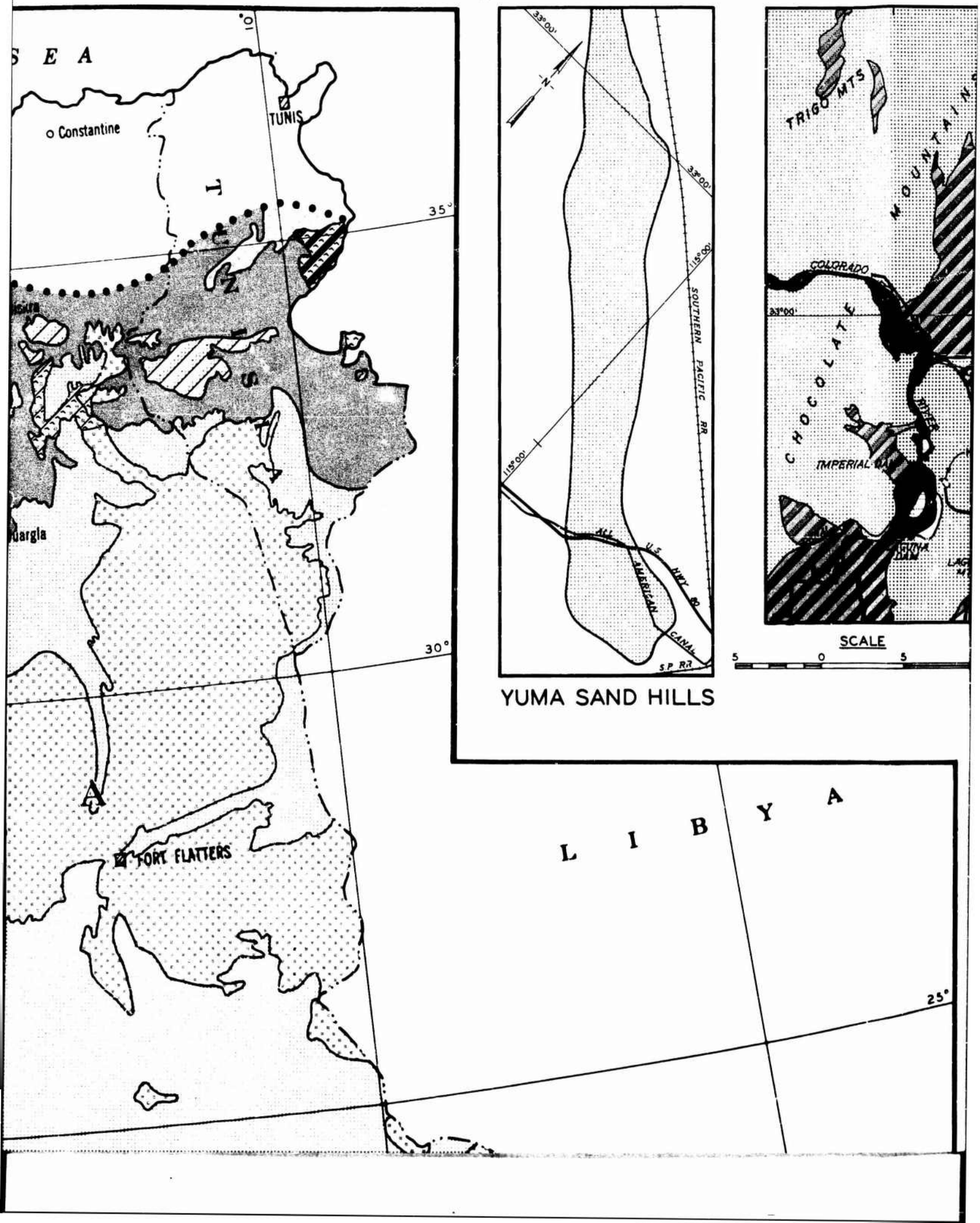
PLATE 8

8

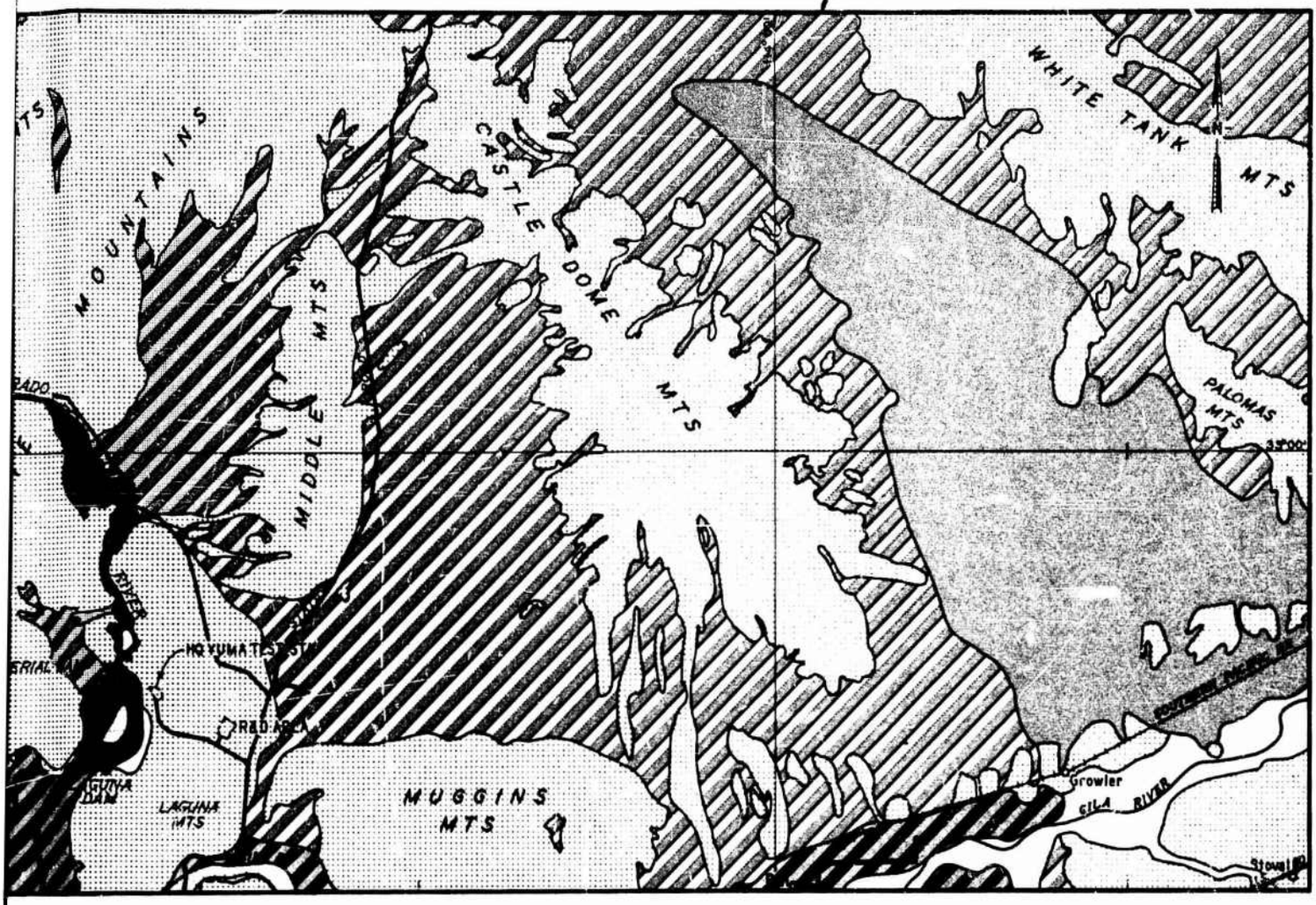

20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
CASABLANC
MARRAKECH
VILLA CISNEROS

2


MEDITERRANEAN
ALGIERS
TANGIER
ORAN
RABAT
ASABLANCA
Colomb Bechar
Ouargla
ALGERI


S E A
Constantine
TUNIS
35°
Ouargla
30°
FORT FLATTERS
L I B Y A
25°
33°00'
115°00'
SOUTHERN PACIFIC RR
U.S. HWY 80
AMERICAN CANAL
S.P. RR
YUMA SAND HILLS
TRIGO MTS
COLORADO
CHOCOLATE
IMPERIAL
SCALE
5 0 5

4



SCALE 5 10 MI.

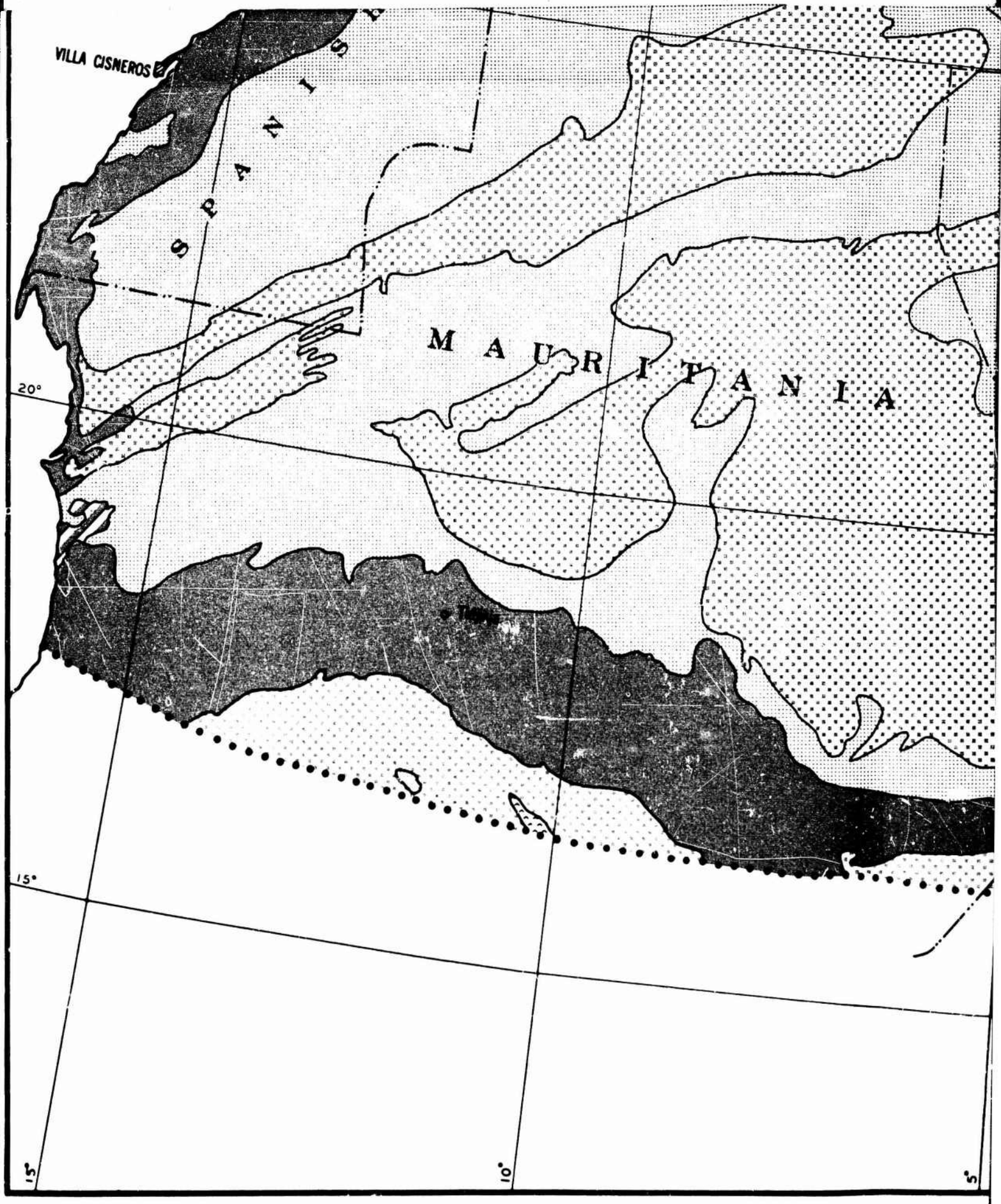
YUMA TEST STATION

25°

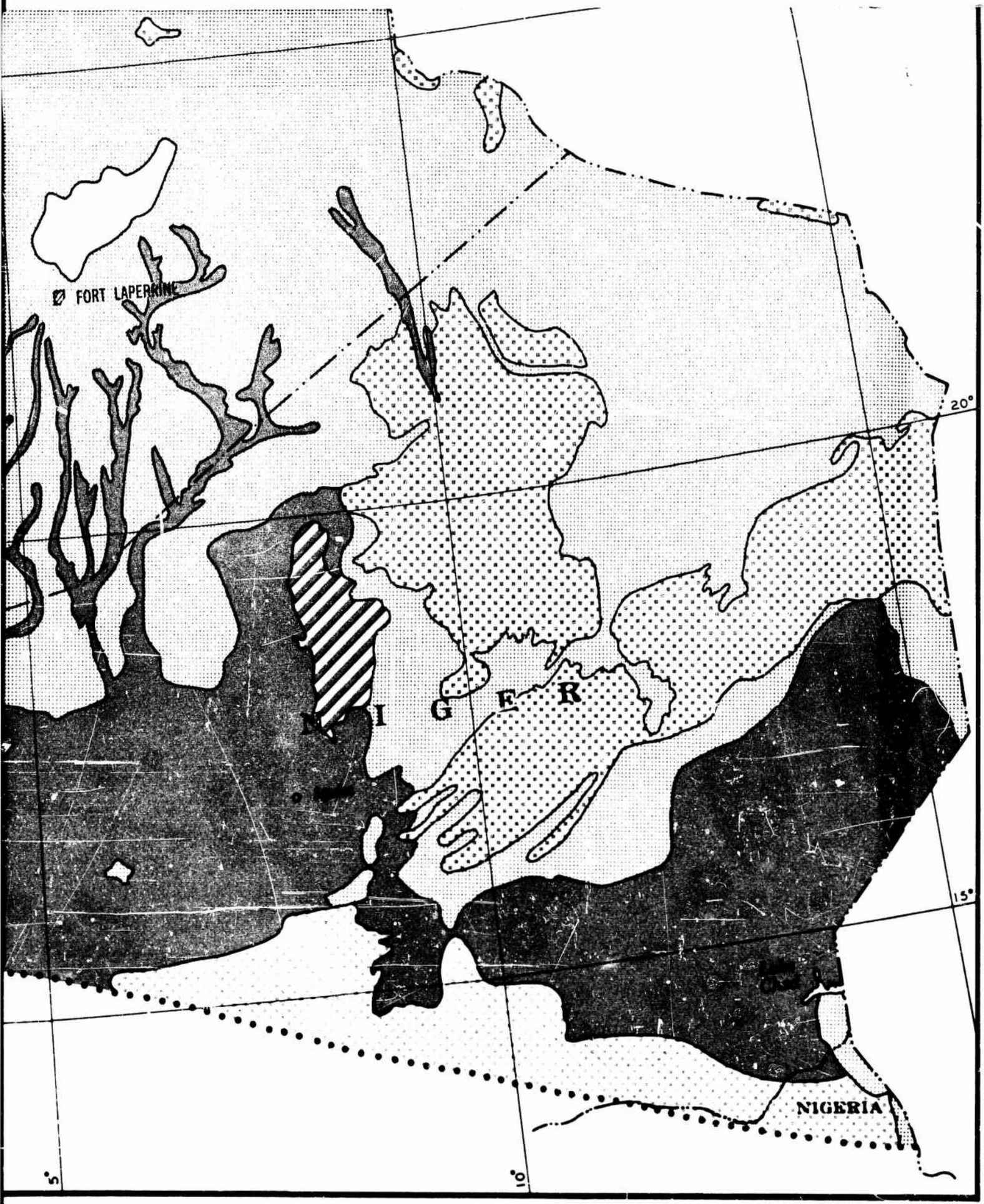
VEGETATION

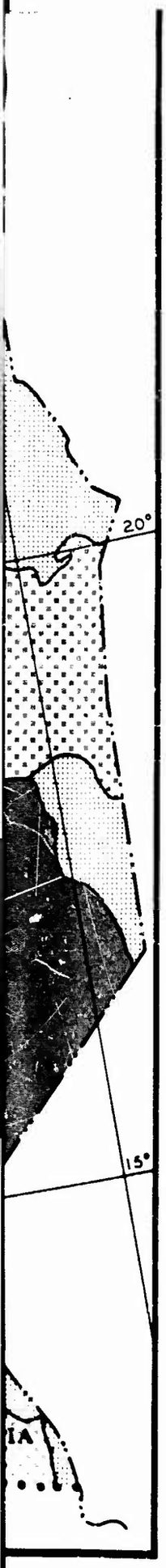
Areally predominant (70 percent or more) vegetation type mapped.

	Unit	Description
1	Barren	Devoid or nearly devoid of vegetation.
2	Sparse shrub & grass	Widely spaced thorny shrubs, bushes, low scrubby trees, herbs, or clumps and open stands of coarse grass. (Also includes cacti in the U. S.)
3	Scattered shrub & grass	Moderate spacing of forms mentioned under unit 2.
4	Scattered shrub and/or scrubby trees	Thin stands of shrubs and scrubby trees, undergrowth (if present) consists of low shrubs, bushes, and grasses.
4a	a. With scattered 3rd-story trees	----------
5	Dense shrub and/or scrubby trees	Dense stands of shrubs and scrubby trees, undergrowth (if present) consists of low shrubs, bushes, and grasses.


VILLA CISNEROS
SPANISH
MAURITANIA
20°
15°
15°
10°
5°


M A L I
Tombouctou
SCALE IN MILES
100
0
100
200
5°
0°
5°


FORT LAPERRINE
20°
15°
5°
10°
NIGERIA



4		Scattered shrub and/or scrubby trees	Thin stands of shrubs and scrubby trees, undergrowth (if present) consists of low shrubs, bushes, and grasses.
4a		a. With scattered 3rd-story trees	----------
5		Dense shrub and/or scrubby trees	Dense stands of shrubs and scrubby trees, undergrowth (if present) consists of low shrubs, bushes, and grasses.
5a		a. With scattered 3rd-story trees	----------
5b		b. With grain-herb cultivation	Orchard areas with grain-herb cultivation forming the 1st story.
6		Palms with or without grain-herb cultivation	Dense palm groves, 1st-story grain-herb cultivation may or may not be present.
7		Steppe	Low grass cover, may or may not include scattered low scrubby trees and shrubs. Height of grass ranges from a few in. to 2 ft.
8		Steppe-savanna	High continuous grass cover, includes scattered scrubby trees and shrubs. Height of grass averages 3-5 ft.
9		Grain-herb cultivation	Cultivated plots of grains, vegetables, etc.
10		Marsh	Dense growth of grasses, sedges, etc.
3/4		VEGETATION COMPLEXES	Vegetation complexes are mapped where no areally predominant (70 percent or more) vegetation type occurs. In such instances, the two most commonly occurring types are mapped; the predominant is shown as the numerator, the subordinate as the denominator in the fractional pattern.
		Palms	

VEGETATION

(Supplementary Data)

Unit	Ground Cover %	Canopy Cover		Spacing		Height		Trunk Diam		Crown Diam	
		2nd* Story %	3rd Story %	2nd Story ft	3rd Story ft	2nd Story ft	3rd Story ft	2nd Story in.	3rd Story in.	2nd Story ft	3rd Story ft
1. Barren	<1	†	†	†	†	†	†	†	†	†	†
2. Sparse shrub & grass	1-5	†	†	†	†	†	†	†	†	†	†
3. Scattered shrub & grass	5-25	0-5	†	much >12	†	6-10	†	2-5	†	5-10	†
4. Scattered shrub and/or scrubby trees	50-90	<50	†	>12	†	6-25	†	2-12	†	5-25	†
With scattered 3rd-story trees	50-90	<45	5-25	>12	>12	6-25	25-50	2-12	12-24	5-25	25-40
5. Dense shrub and/or scrubby trees	80-100	>50	†	<12	†	6-25	†	2-12	†	5-25	†
a. With scattered 3rd-story trees	80-100	>50	5-25	<12	>12	6-25	25-50	2-12	12-24	5-25	25-40
b. With grain-herb cultivation	90-100	>50	†	>12	†	10-20	†	5-10	†	10-20	†
6. Palms with or without grain-herb cultivation	75-100	†	50-75	†	>12	†	40-60	†	12-24	†	20-30
7. Steppe	50-100	†	†	†	†	†	†	†	†	†	†
8. Steppe-savanna	90-100	5-10	†	much >12	†	15-25	†	7-12	†	15-25	†
9. Grain-herb cultivation	90-100	†	†	†	†	†	†	†	†	†	†
10. Marsh	80-100	†	†	†	†	†	†	†	†	†	†

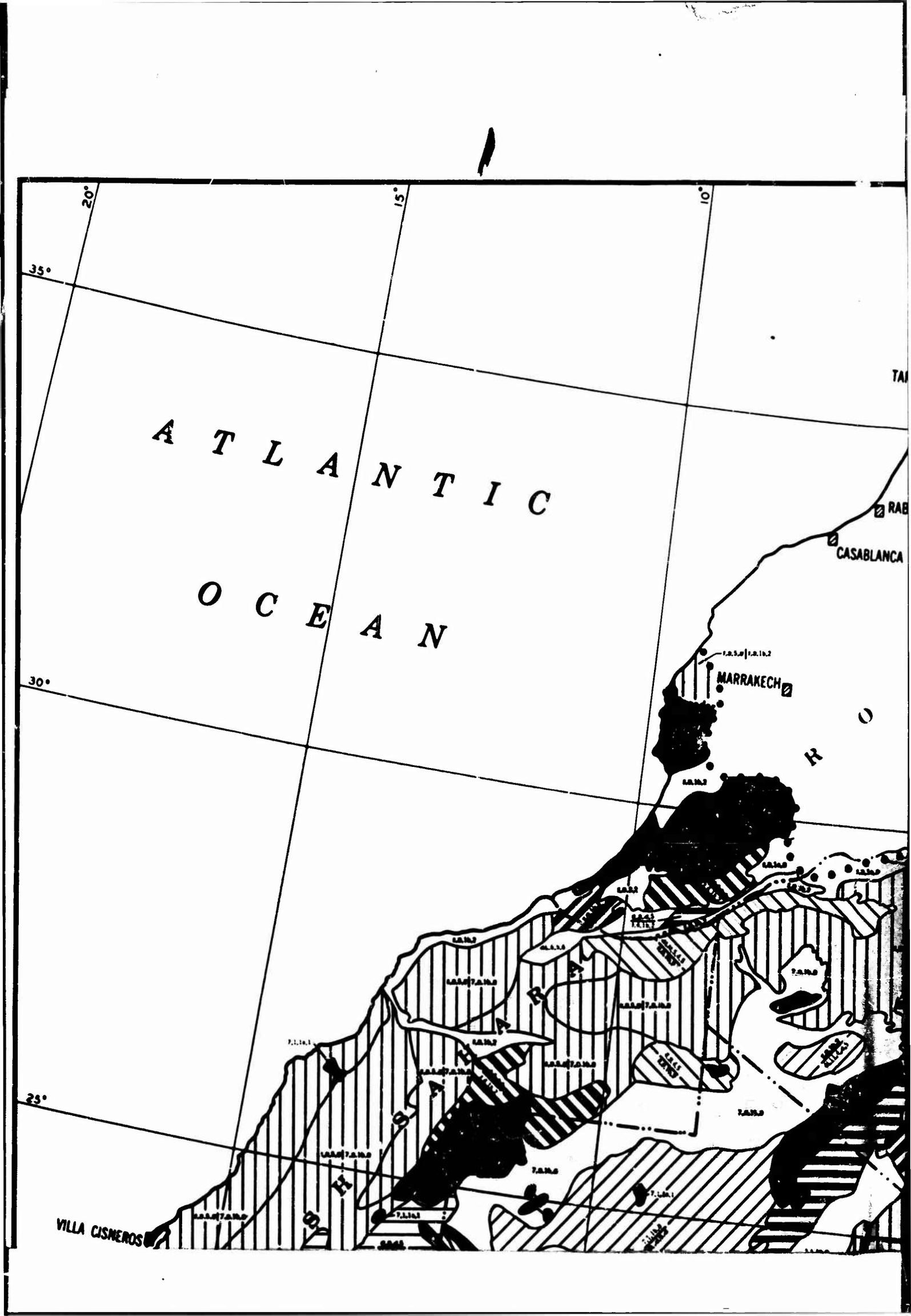
* Vegetation stories are distinguished on the basis of height: 1st-story vegetation ranges from 0 to 6 ft in height; 2nd story, from 6 to 25 ft; 3rd story, from 25 to 70 ft.

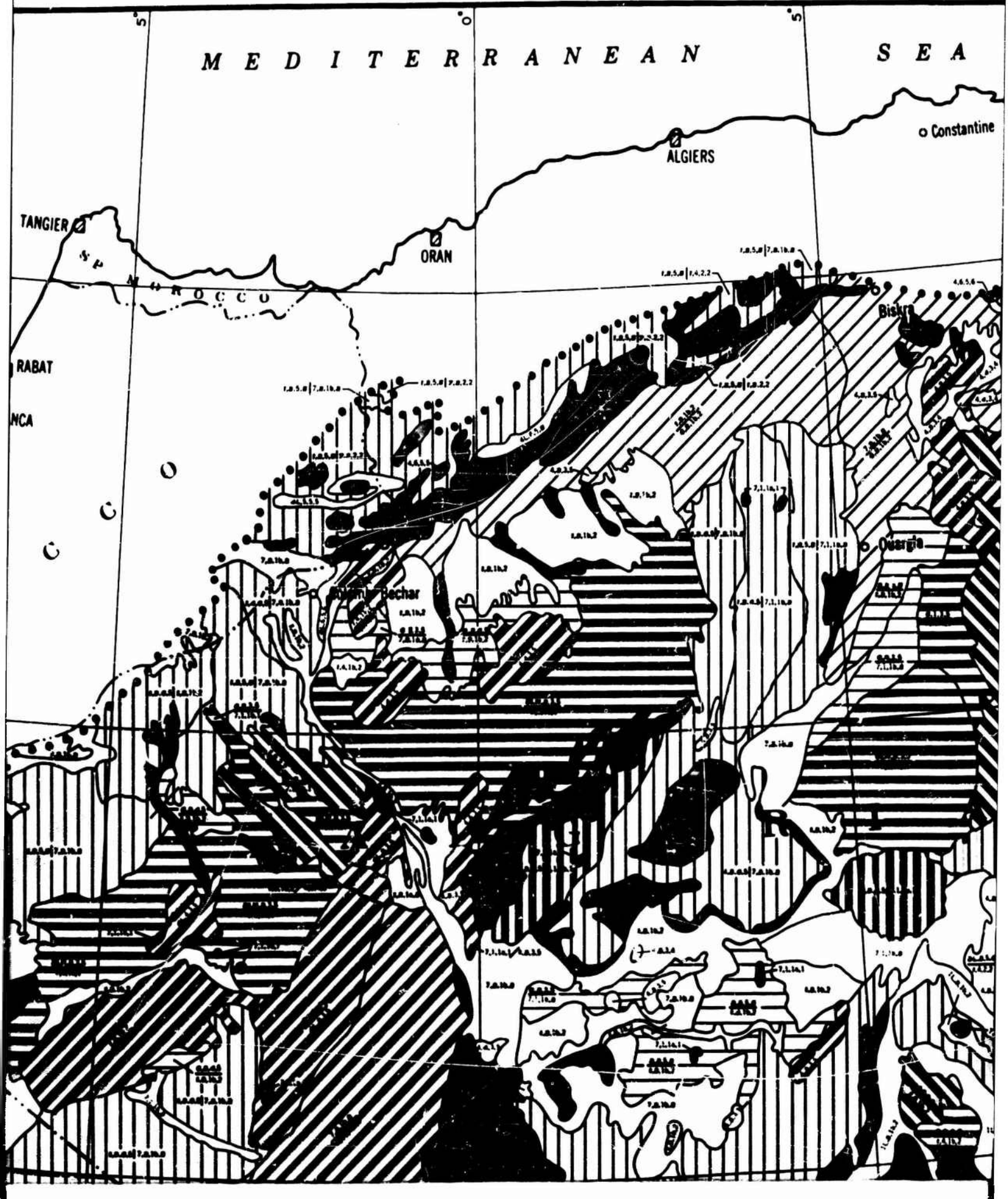
† Indicates factor is unimportant or not applicable within the vegetation unit.

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT
VEGETATION

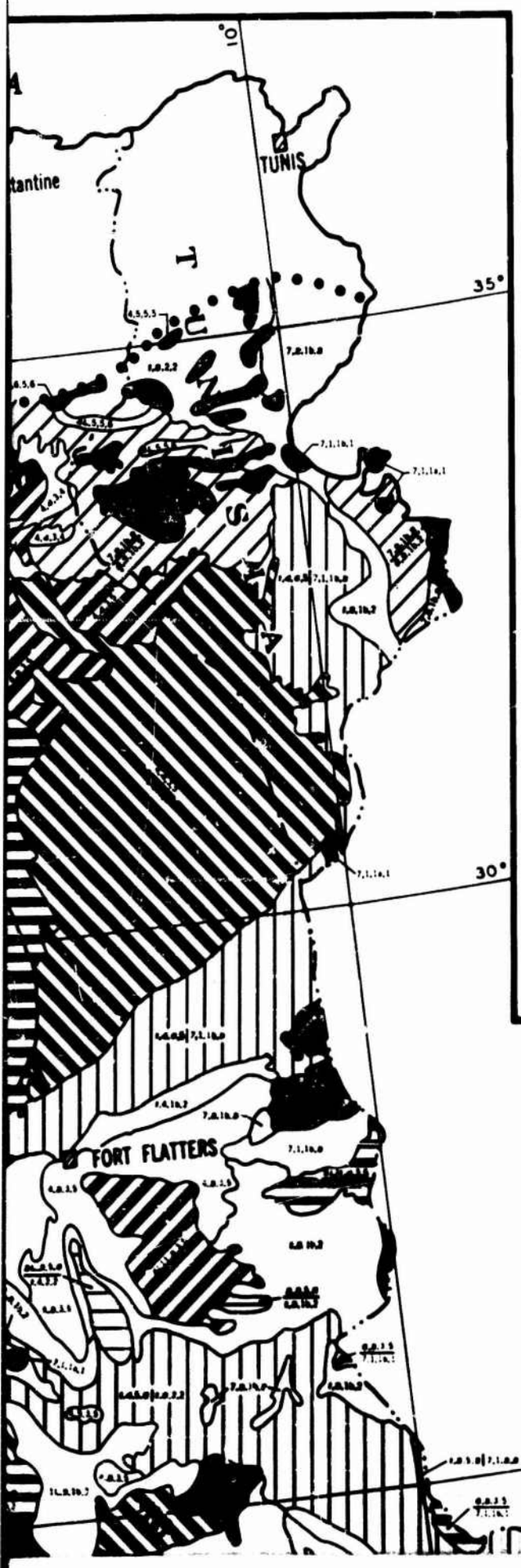
PLATE 9

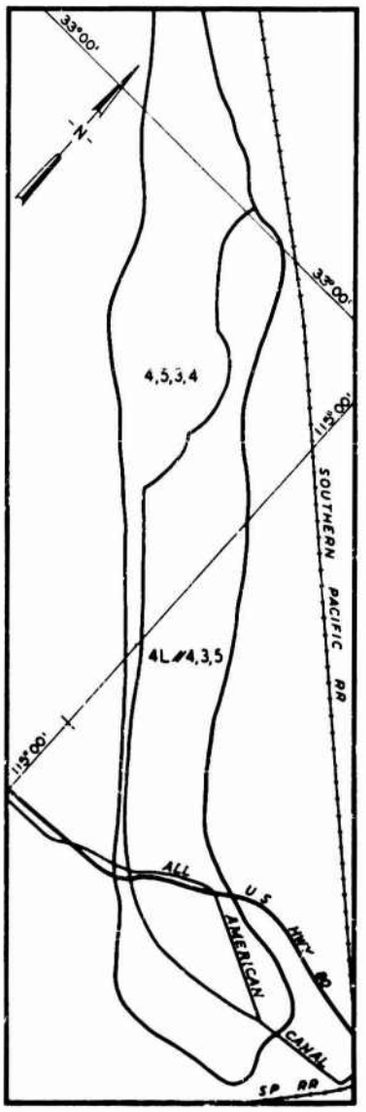
8

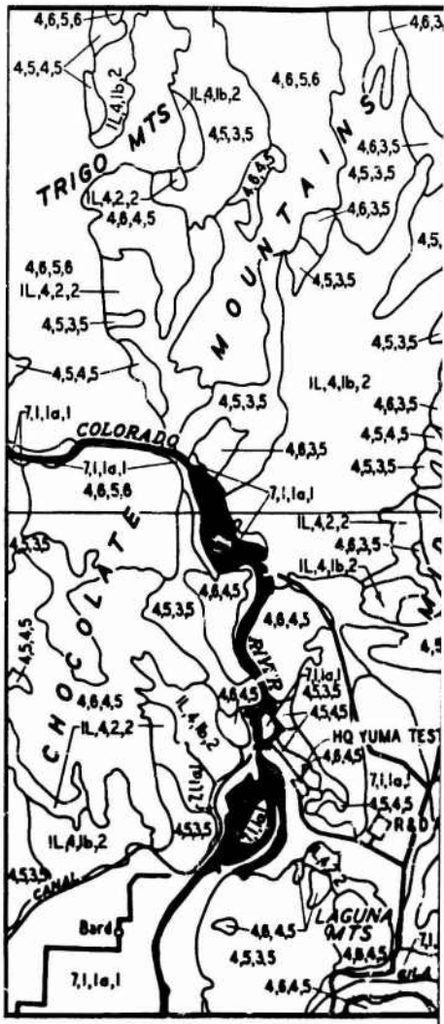

20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
CASABLANCA
MARRAKECH
VILLA CISNEROS


MEDITERRANEAN SEA
ALGIERS
Constantine
TANGIER
ORAN
MOROCCO
RABAT
Biskra
Ouargla
Bechar

3

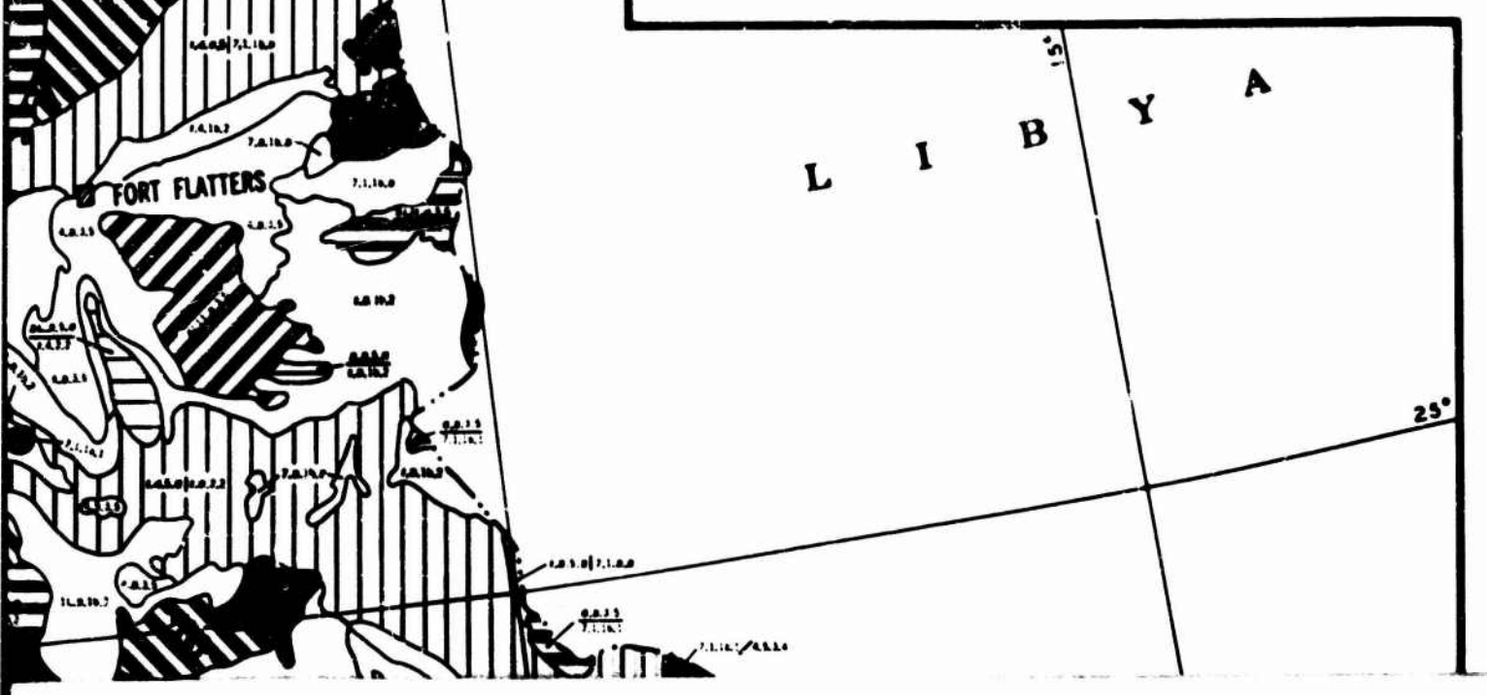




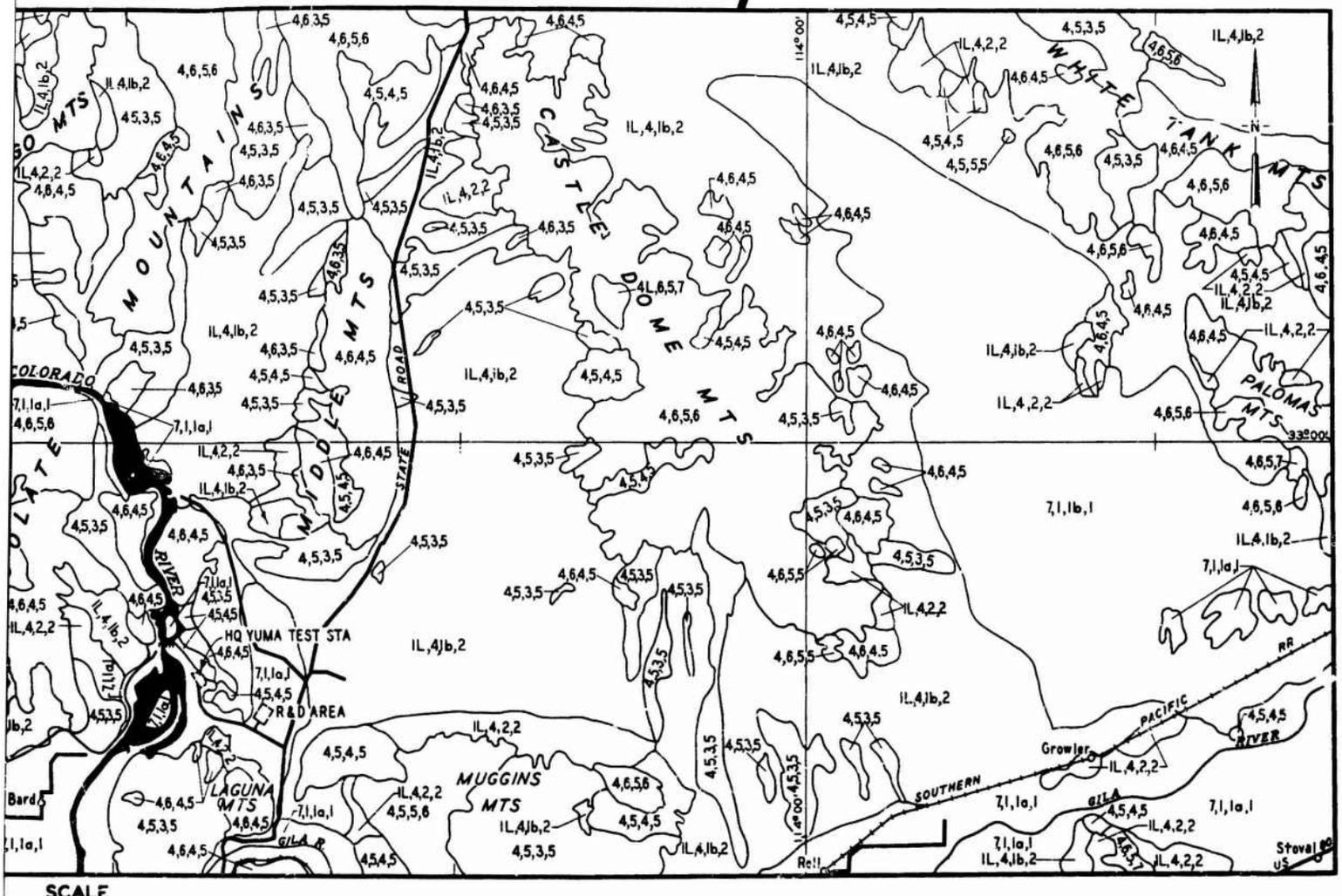


YUMA SAND HILLS

(GROSS LANDSCAPE: 6L,1,3,5)



4



YUMA TEST STATION

(GROSS LANDSCAPE: 5L//,1,5,7)

A

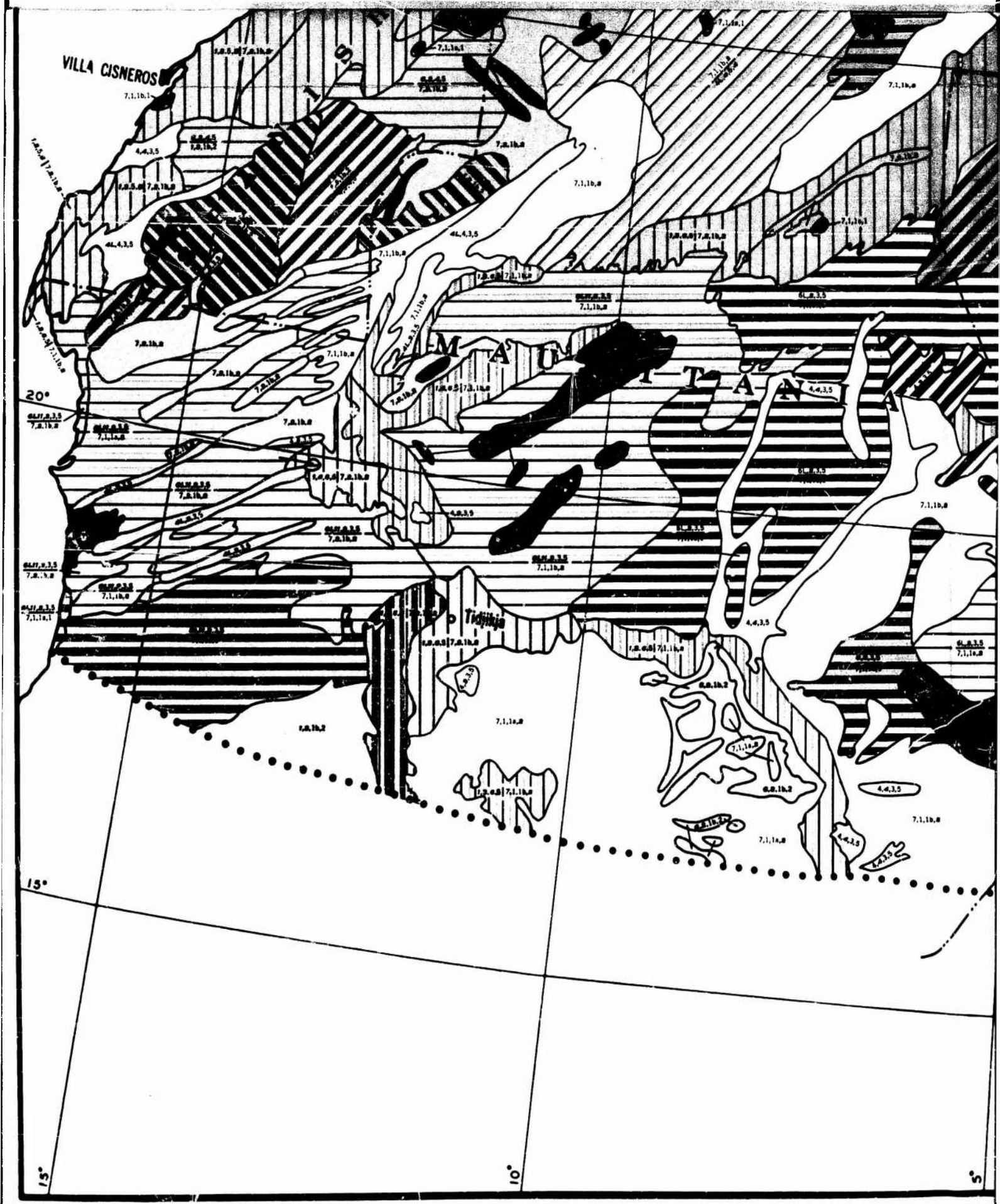
25°

GEOMETRY OR FORM ANALOGS

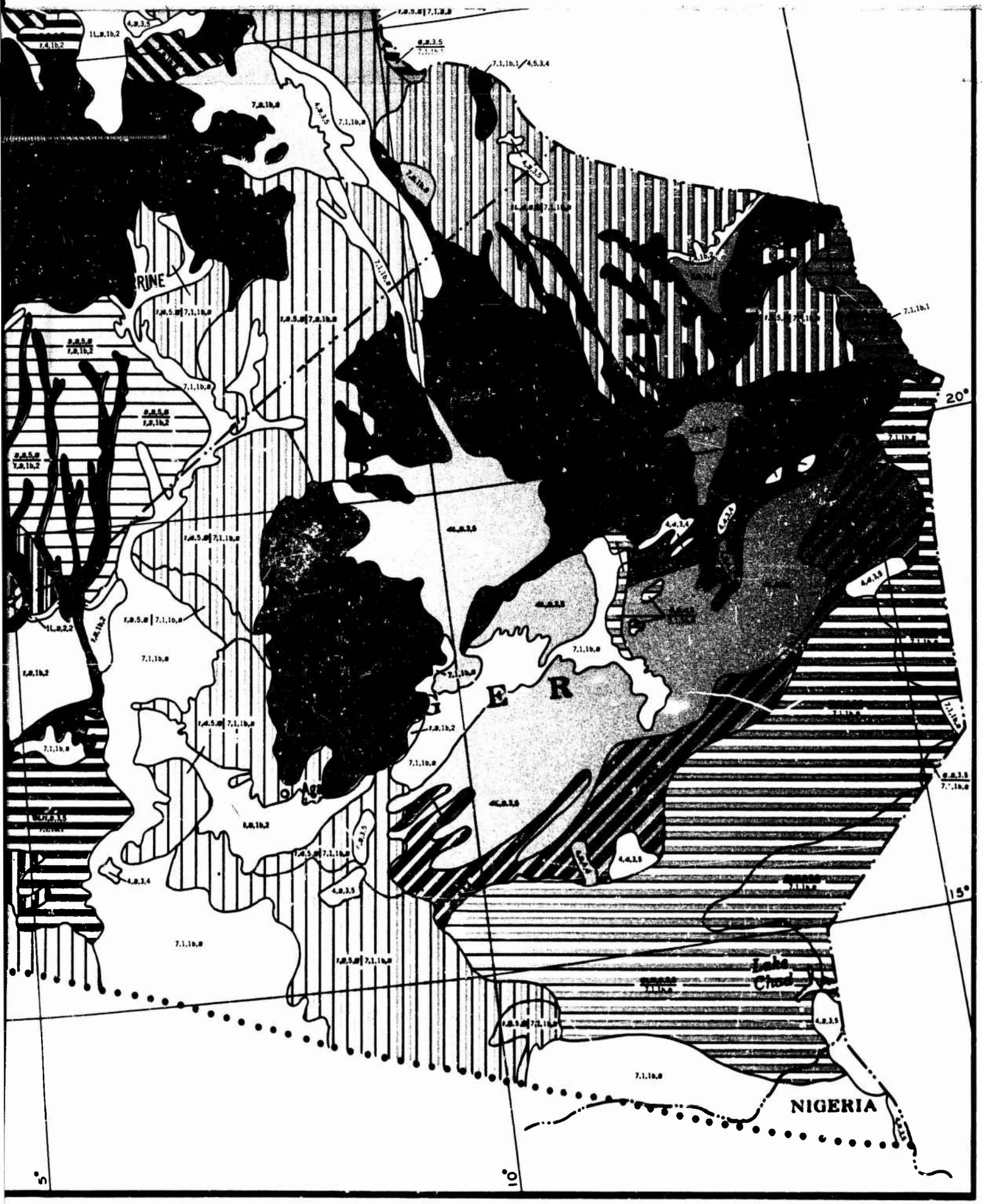
LEGEND

4,4,3,5 Each landscape type is identified by a series or an array of four symbols indicating mapping units of PLAN-PROFILE (4), SLOPE OCCURRENCE (5), SLOPE (3), and RELIEF (5). Mapping units of these four factors are always designated in this order.

4,4,3,5 Landscapes in Northwest Africa are always compared with Yuma landscapes and


VILLA CISNEROS
MAURITANIA
Tidjikja
20°
15°
15°
10°
5°


M A L I
Niger River
SCALE IN MILES
100 0 100 200
5°
0°
5°


RINE
G E R
Lake Chad
NIGERIA
20°
15°
10°
5°

4,5,3,5 Each landscape type is identified by a series or an array of four symbols indicating mapping units of PLAN-PROFILE (4), SLOPE OCCURRENCE (5), SLOPE (3), and RELIEF (5). Mapping units of these four factors are always designated in this order.

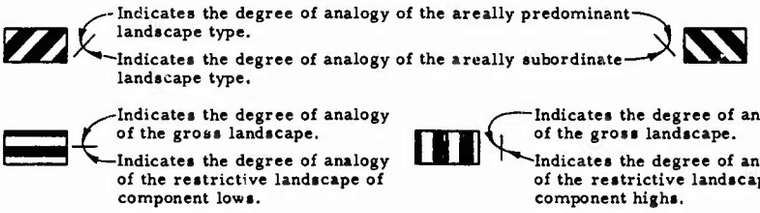
4,4,3,5 Landscapes in Northwest Africa are always compared with Yuma landscapes and not vice versa. The array of symbols in Northwest Africa is shown in light- and boldface type to indicate the maximum degree of analogy with Yuma, the analogy increasing as the number of lightface units increases. Units shown in boldface type are not found at Yuma in combination with the remaining units of the array. Units in lightface type indicate the maximum number of units found in the closest-corresponding array on the Yuma map.*

6L,B,3,5 / 7,1,1b,B Areal Complex. The areally predominant landscape is the numerator of the complex, the subordinate the denominator.

GLM,B,3,5 / 7,1,1b,1 Gross-Component Complex. The gross landscape is compared only with other gross landscapes.

4	Highly Analogous	The identical landscape is found at Yuma.
3	Moderately Analogous	Three units of the array are found in an array occurring at Yuma.
1.5	Slightly Analogous	One or two units of the array are found in an array at Yuma.
0	Not Analogous	No unit of the array is found at Yuma.

LANDSCAPE COMPLEXES:



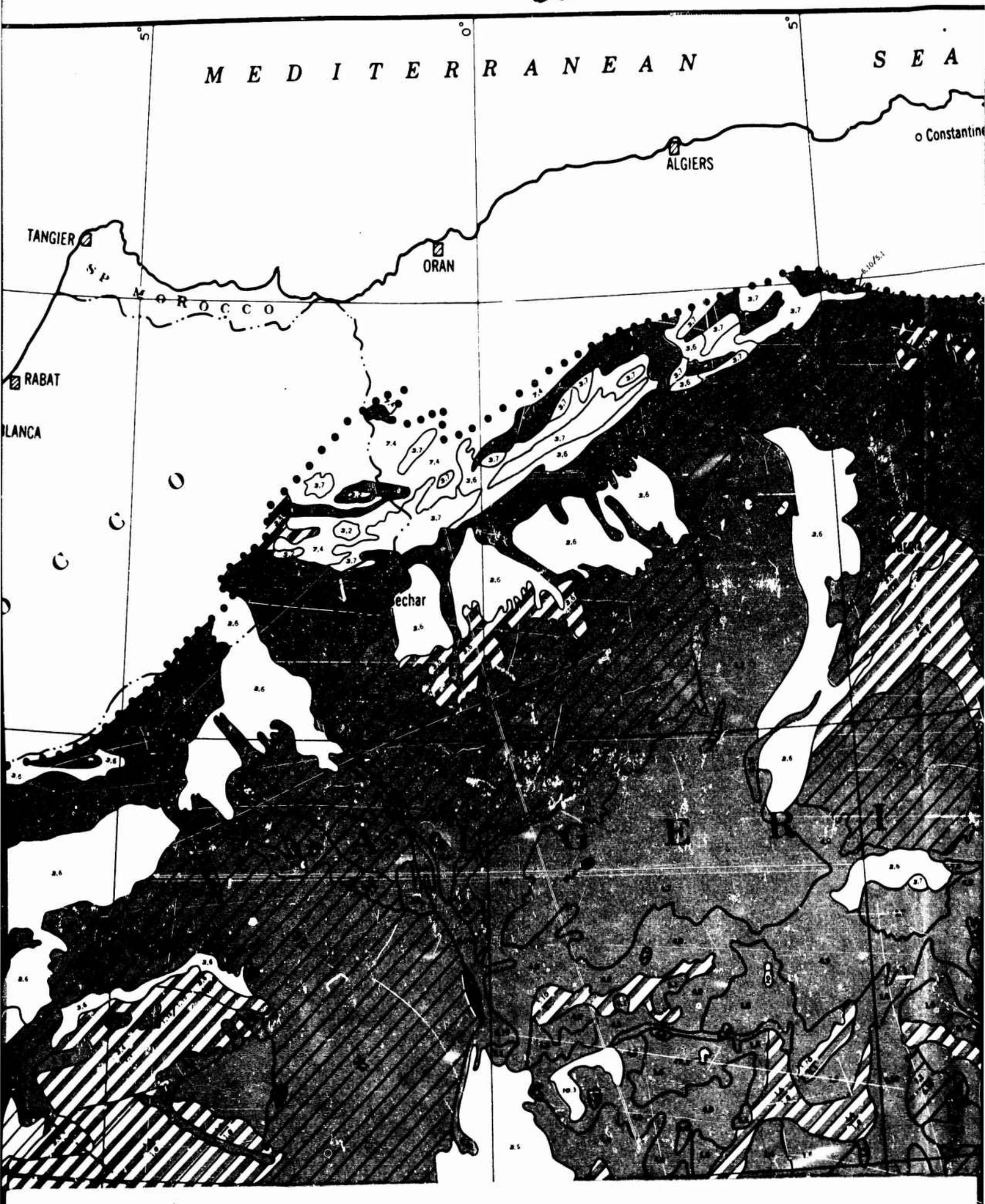
* In a particular array it may be possible to choose different sets of light- or boldface units to indicate the maximum degree of analogy. In such instances units are compared in the order given in the array. For example, the Northwest African array 7,1,B,B was compared with the Yuma array 7,1,1b,1 rather than with Yuma 1L4,2,2 . Comparison with the latter would have resulted in the symbolization 7,B,2,2 .

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT
GEOMETRY ANALOGS

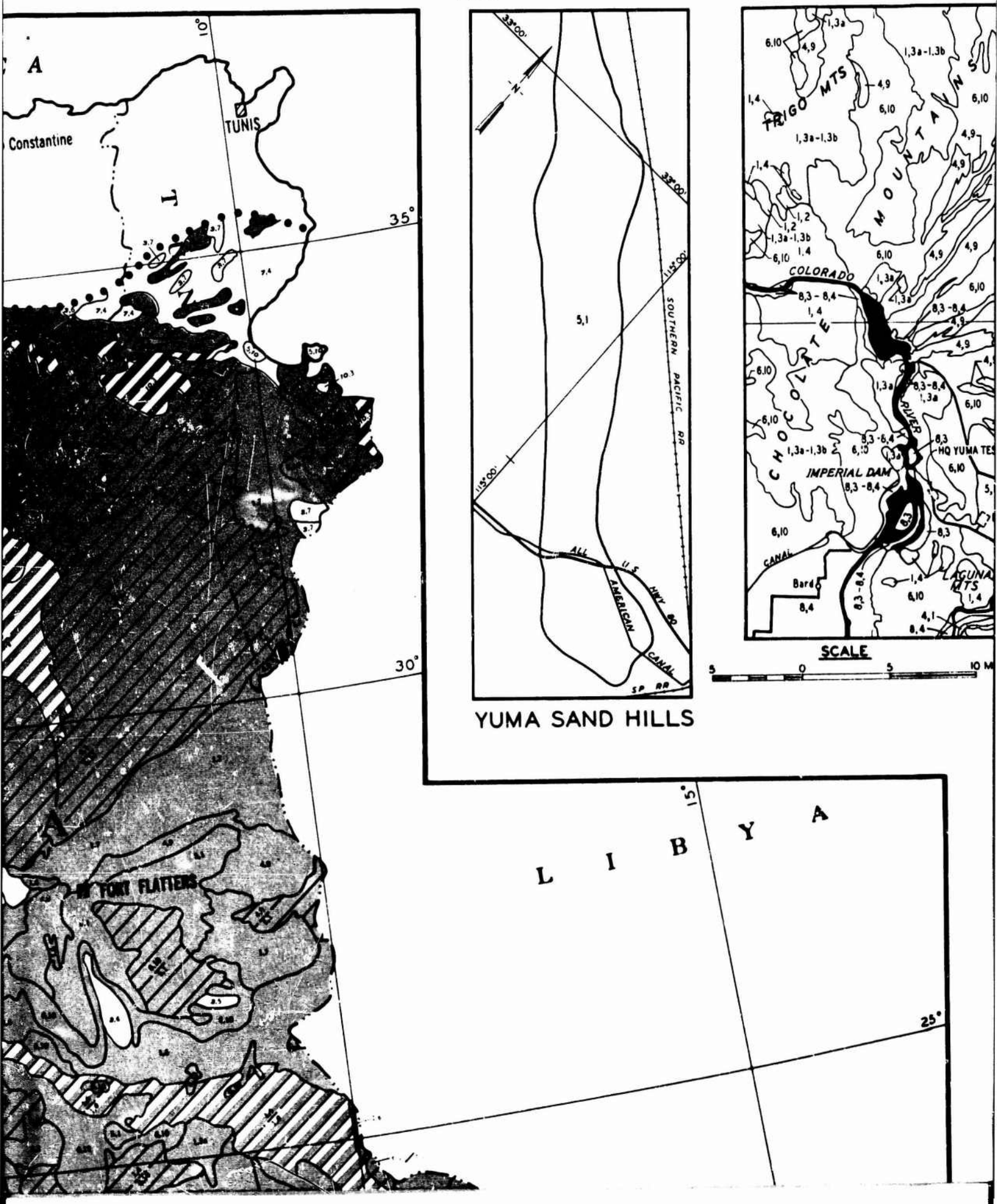
PLATE 10


20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
CASABLANCA
MARRAKECH
Mogador
SAHARA
VILLA CISNEROS

2

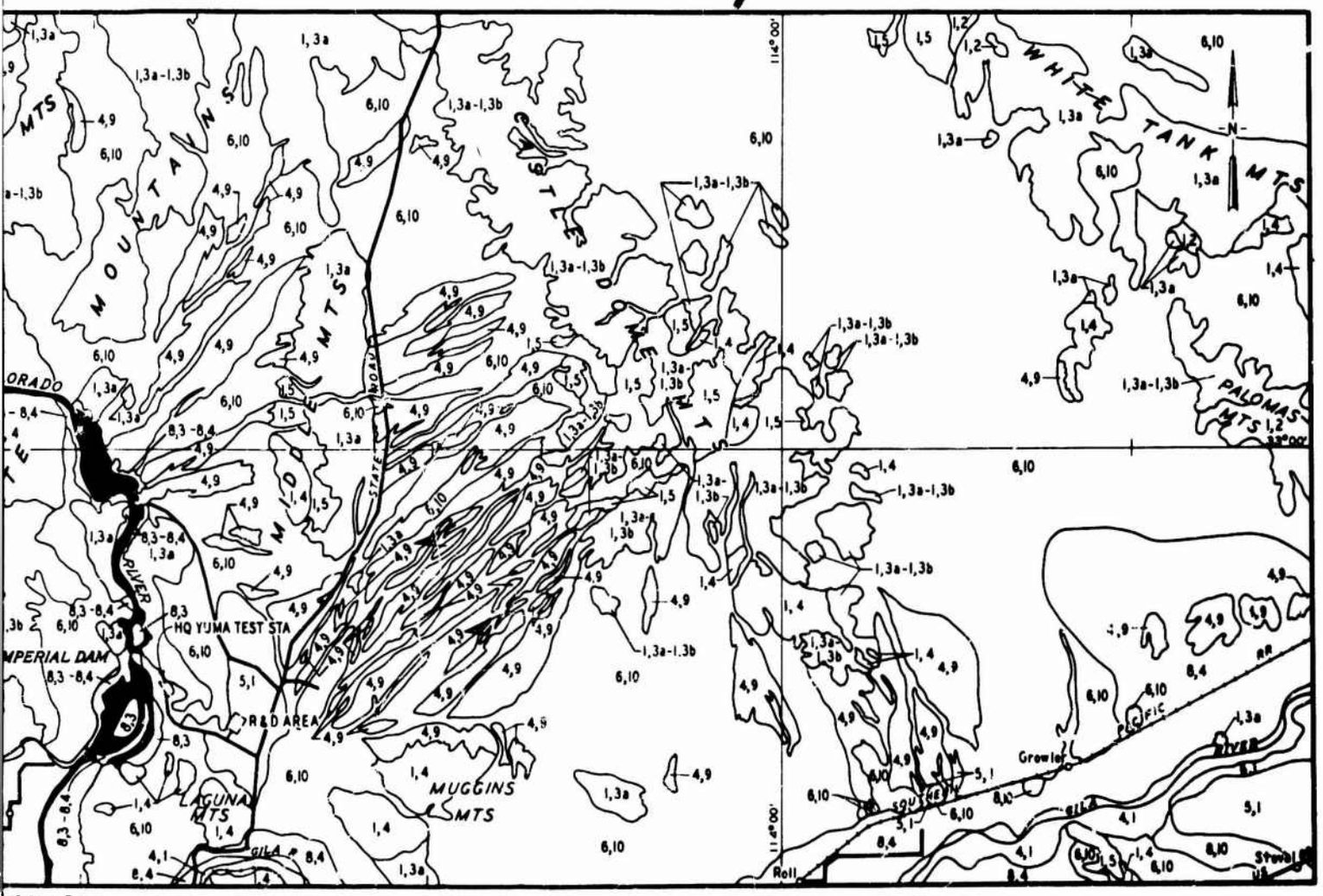

MEDITERRANEAN
SEA
ALGIERS
Constantine
TANGIER
ORAN
SPANISH MOROCCO
RABAT
echar

3



YUMA SAND HILLS

4



SCALE

5 10 MI

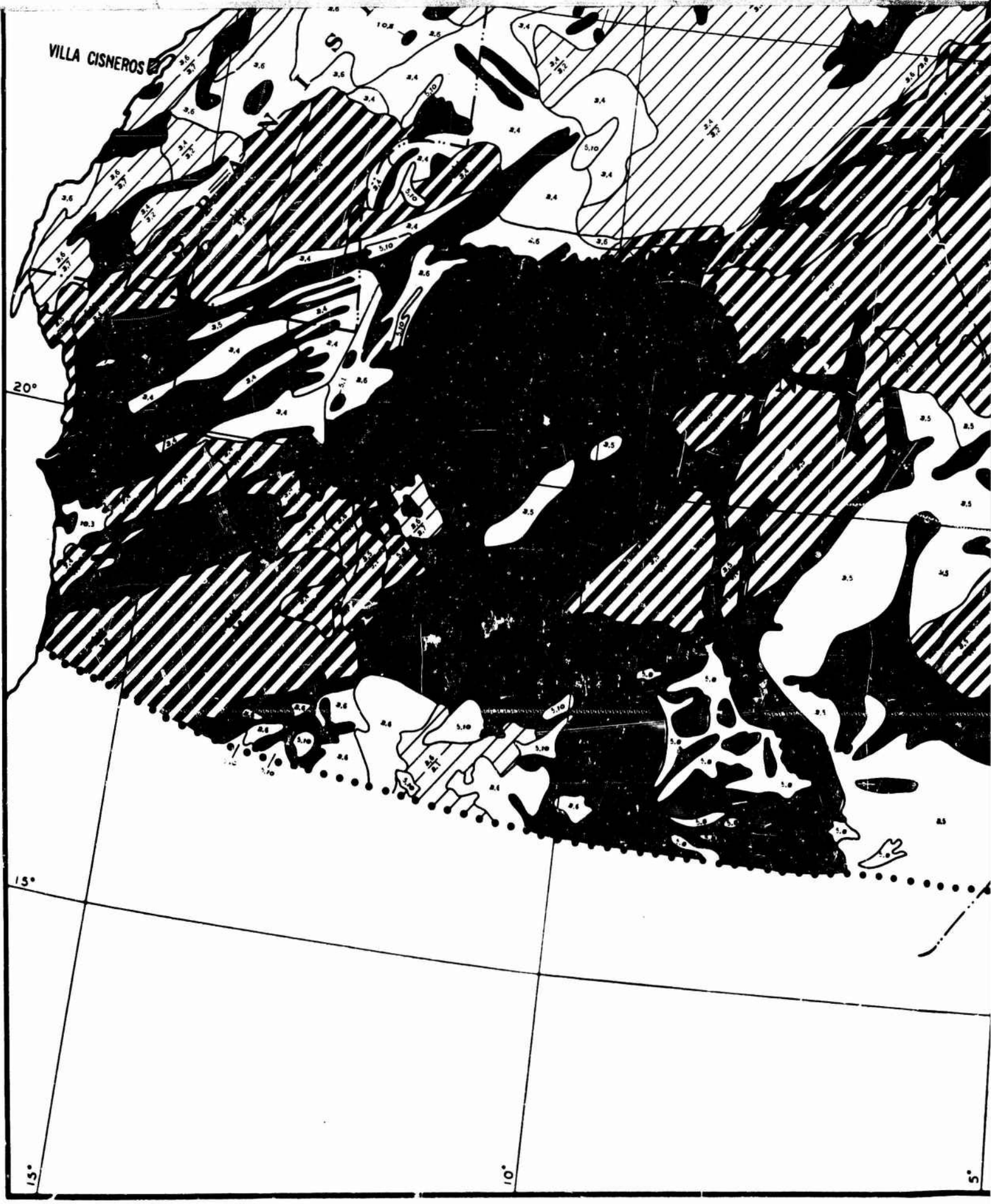
YUMA TEST STATION

25°

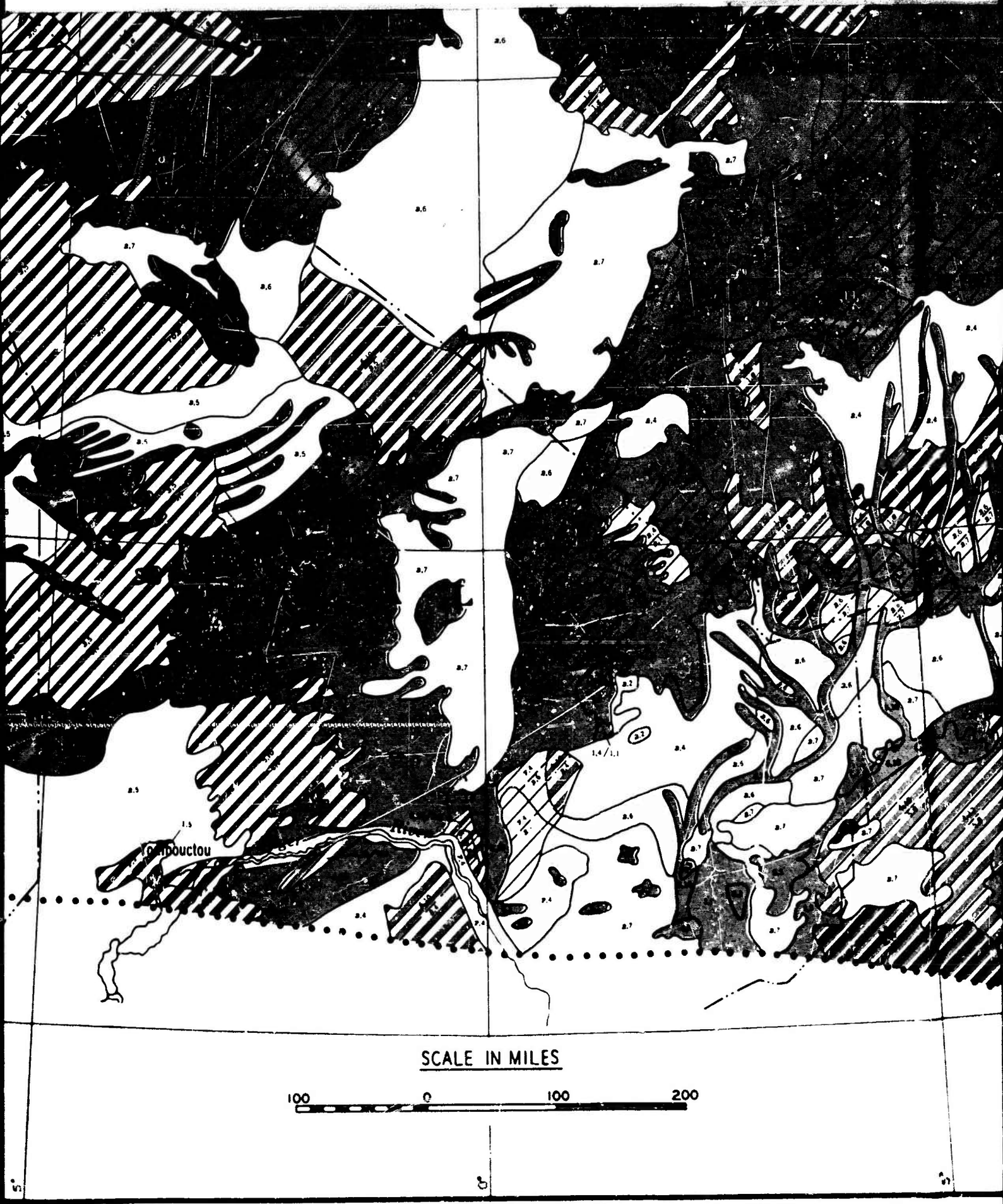
GROUND ANALOGS

LEGEND

1' Numbers designate mapping units of soil type and surface rock or soil



5


Tombouctou
SCALE IN MILES
100
0
100
200


6.10/5.1
2.4
2.6
5.1
5.10
3.7
20°
15°
10°
5°

LEGEND

1,7 Numbers designate mapping units of soil type and surface rock or soil consistency, respectively. If the soil type (first number) is 1, 2, or 3, the second digit designates a surface-rock mapping unit; if the soil type (first number) is 4 or higher, the second number designates a soil-consistency mapping unit. In the example given, e.g. 1.7, the first digit is soil type, the second, surface rock.

3,5 Ground factors in Northwest Africa are always compared with Yuma ground factors and not vice versa. If both digits are lightface, the units designated are found in combination at Yuma. If one is light- and the other boldface, a combination exists at Yuma containing the lightface unit. If both digits are boldface, neither unit is found at Yuma.

5.1 /6,10 Indicates area of ground complex. Two definite soil type-surface rock or soil-consistency combinations are present, but the scale mapping precludes delineation. The areally predominant ground factor appears first in the complex.

2	Highly Analogus	Combination found at Yuma.
1	Partially Analogous	One of the two units is found at Yuma.
0	Not Analogous	None of the units are found at Yuma.

GROUND FACTOR COMPLEXES:

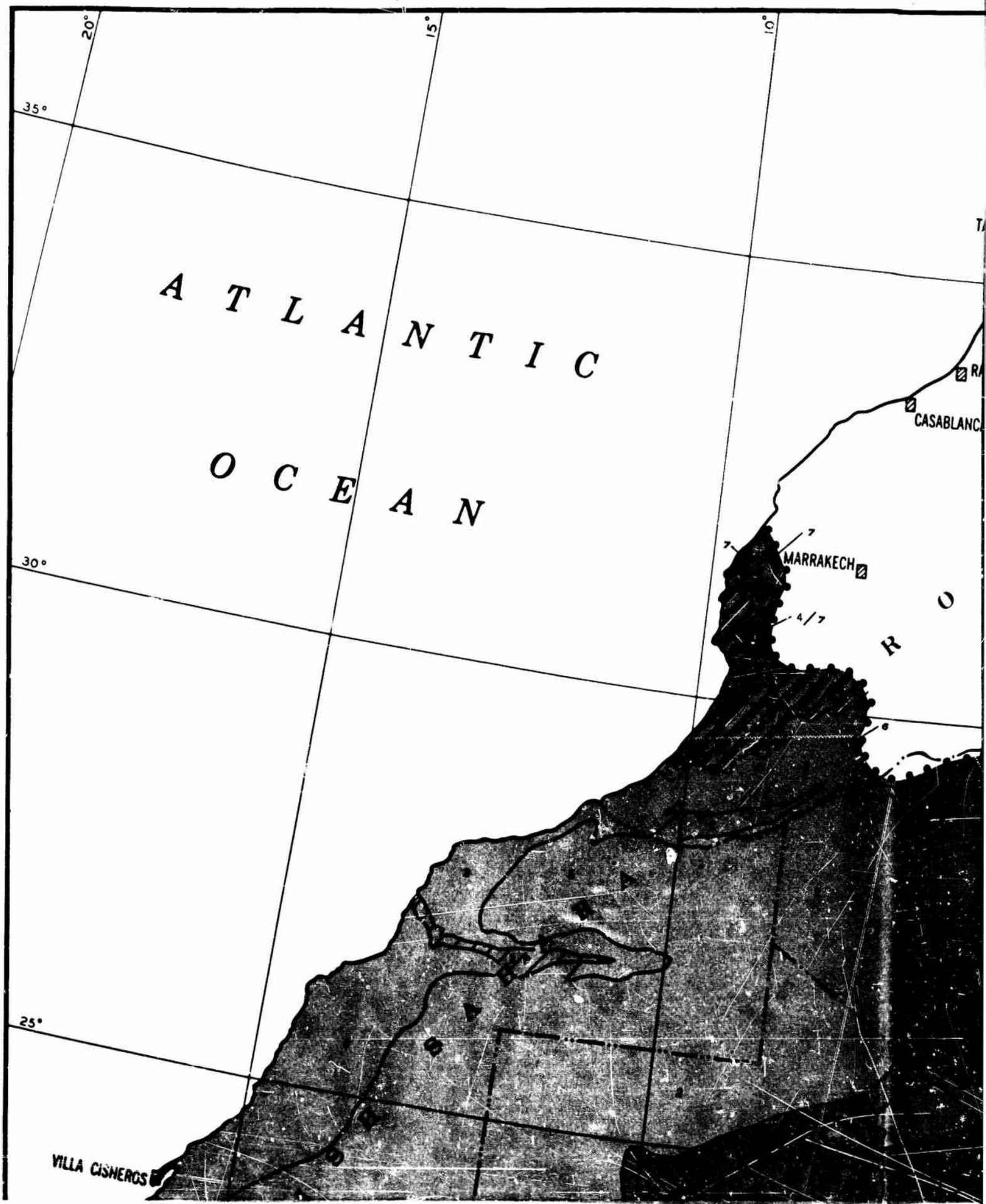
Indicates the degree of analogy of the predominant ground factor array.

Indicates the degree of analogy of the subordinate ground factor array.

* At Yuma surface rock unit 5 (sedimentaries undifferentiated) includes units 6, 7, and 8 (sandstone, limestone, and shale); therefore, where these units are mapped in Northwest Africa, they are designated by lightface symbols.

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT
GROUND ANALOGS

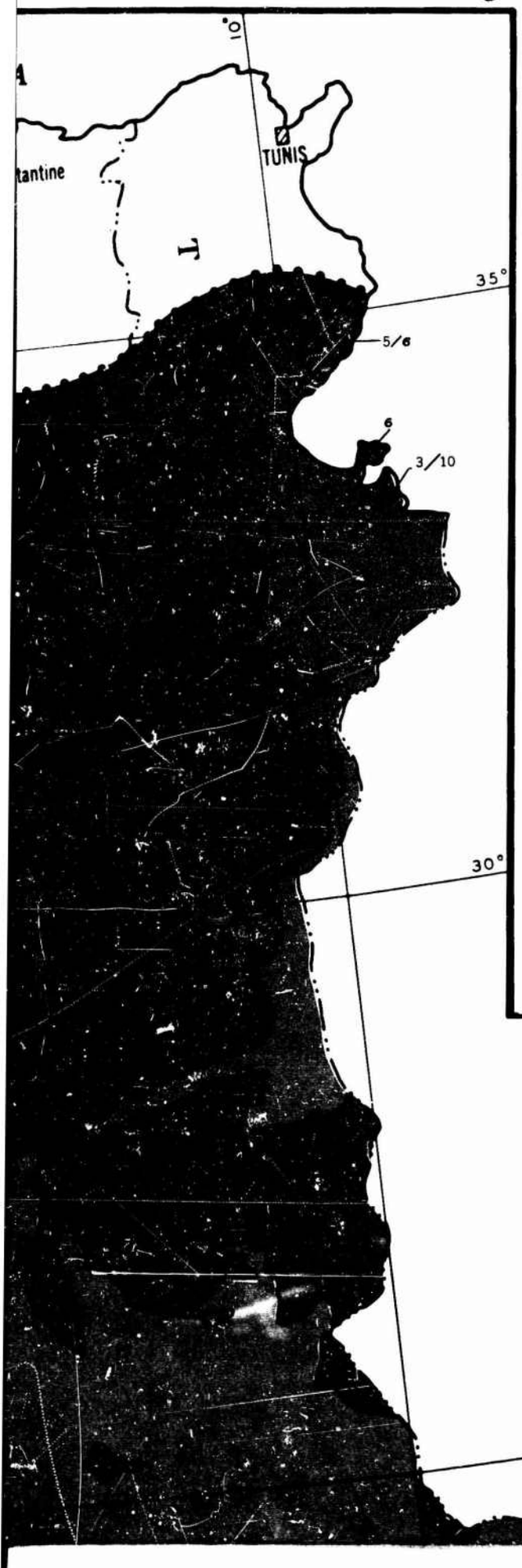
PLATE II

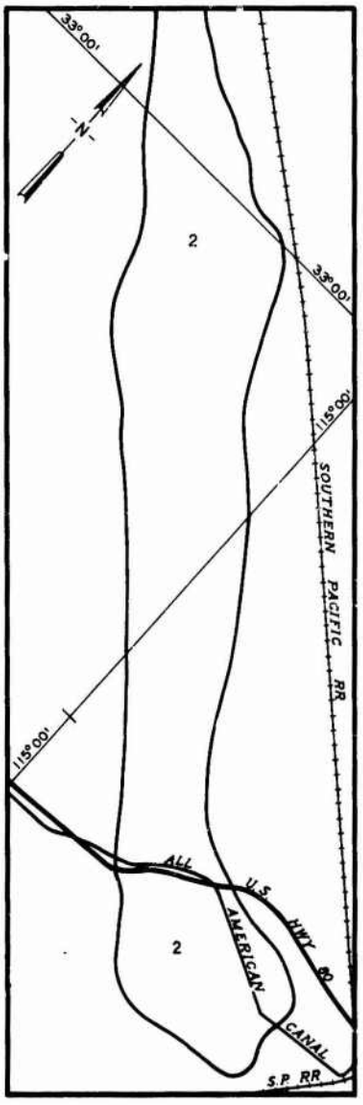

20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
MARRAKECH
CASABLANC
VILLA CISNEROS

2

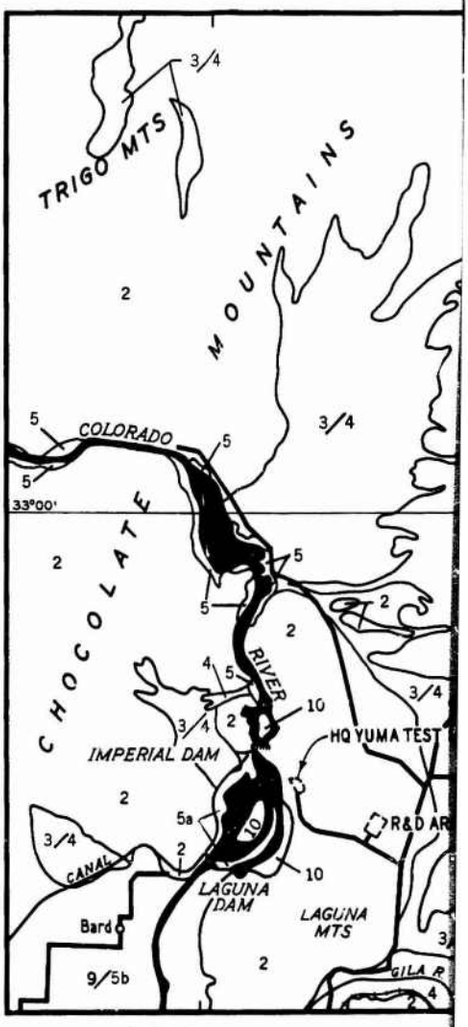

MEDITERRANEAN
SEA
TANGIER
ORAN
ALGIER
Constantin
MOROCCO
RABAT

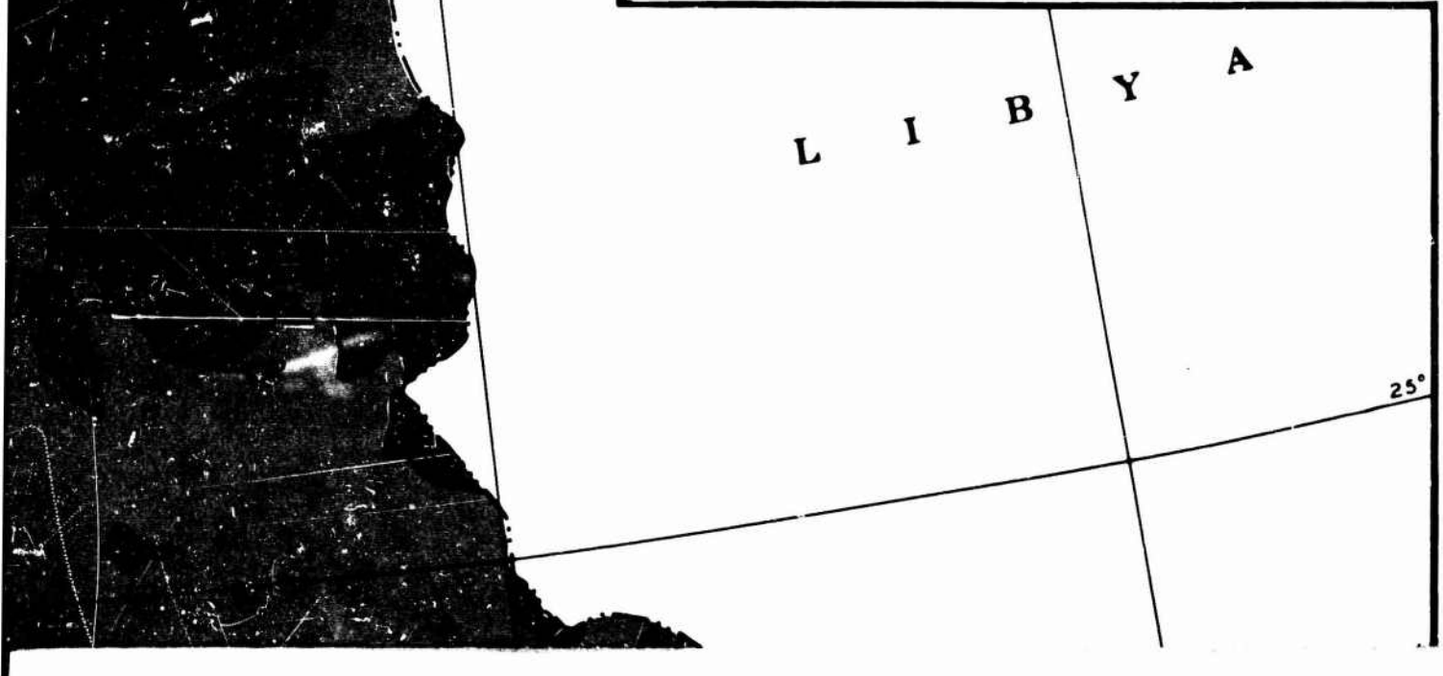
3



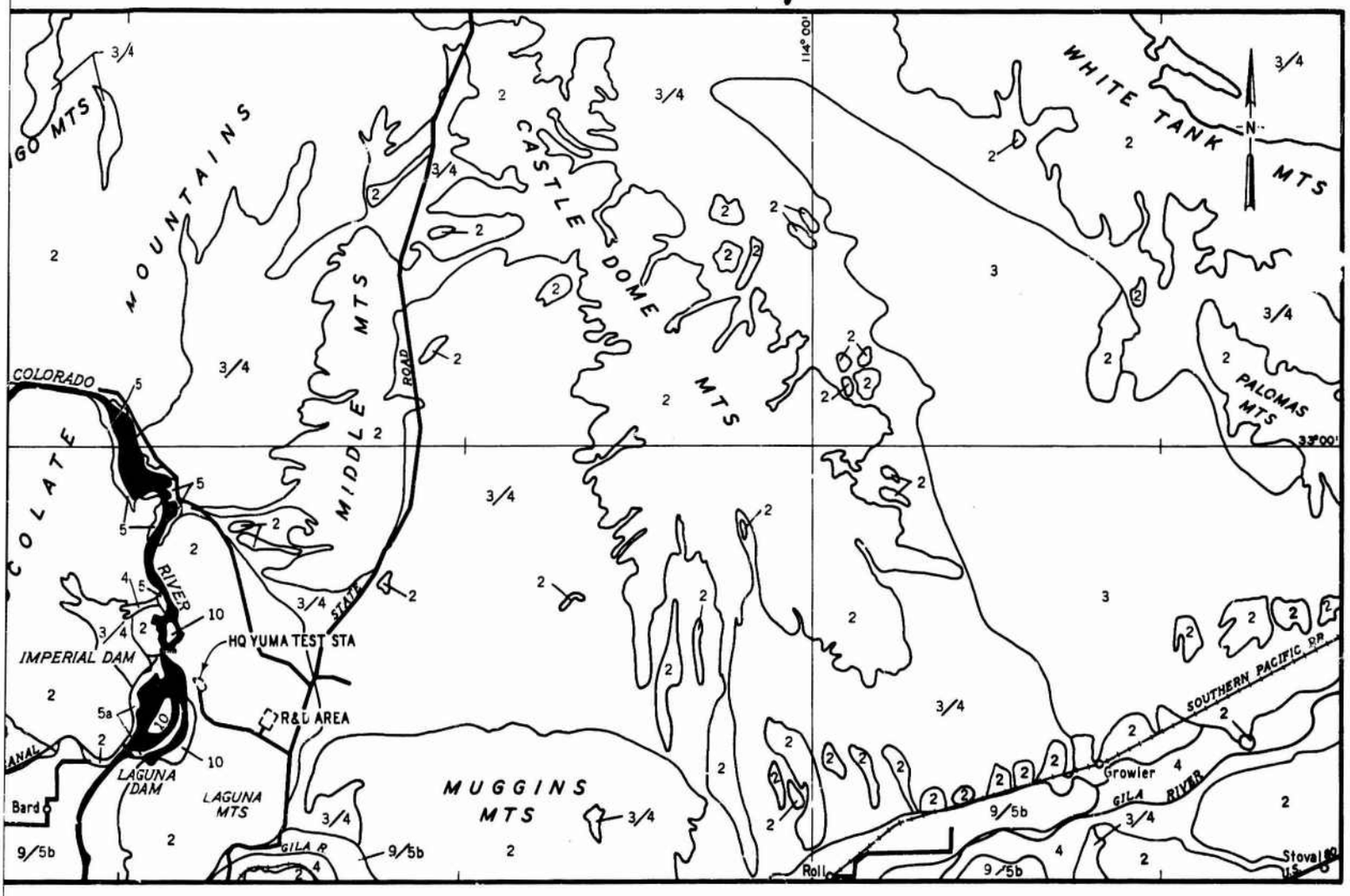


YUMA SAND HILLS





4

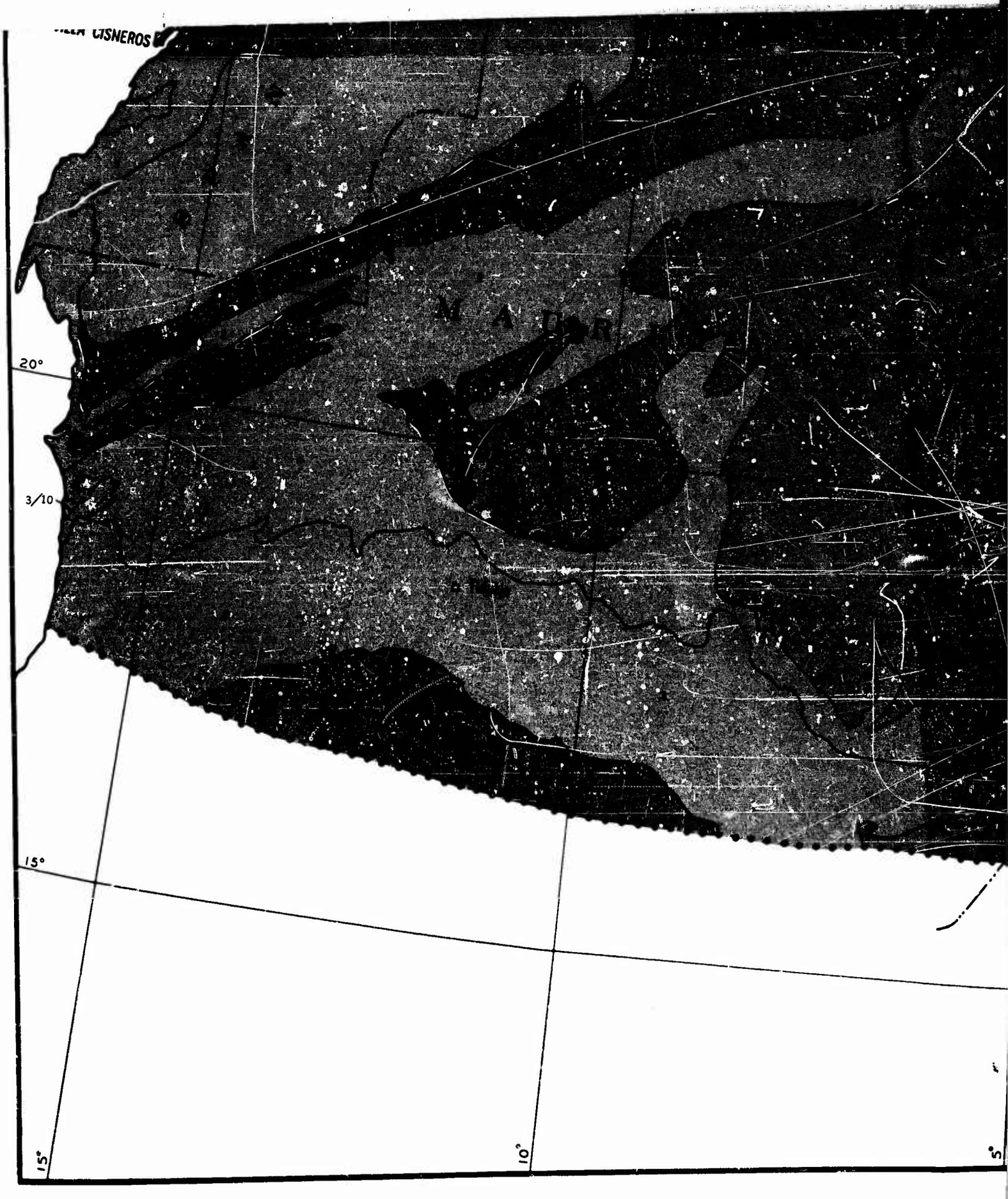


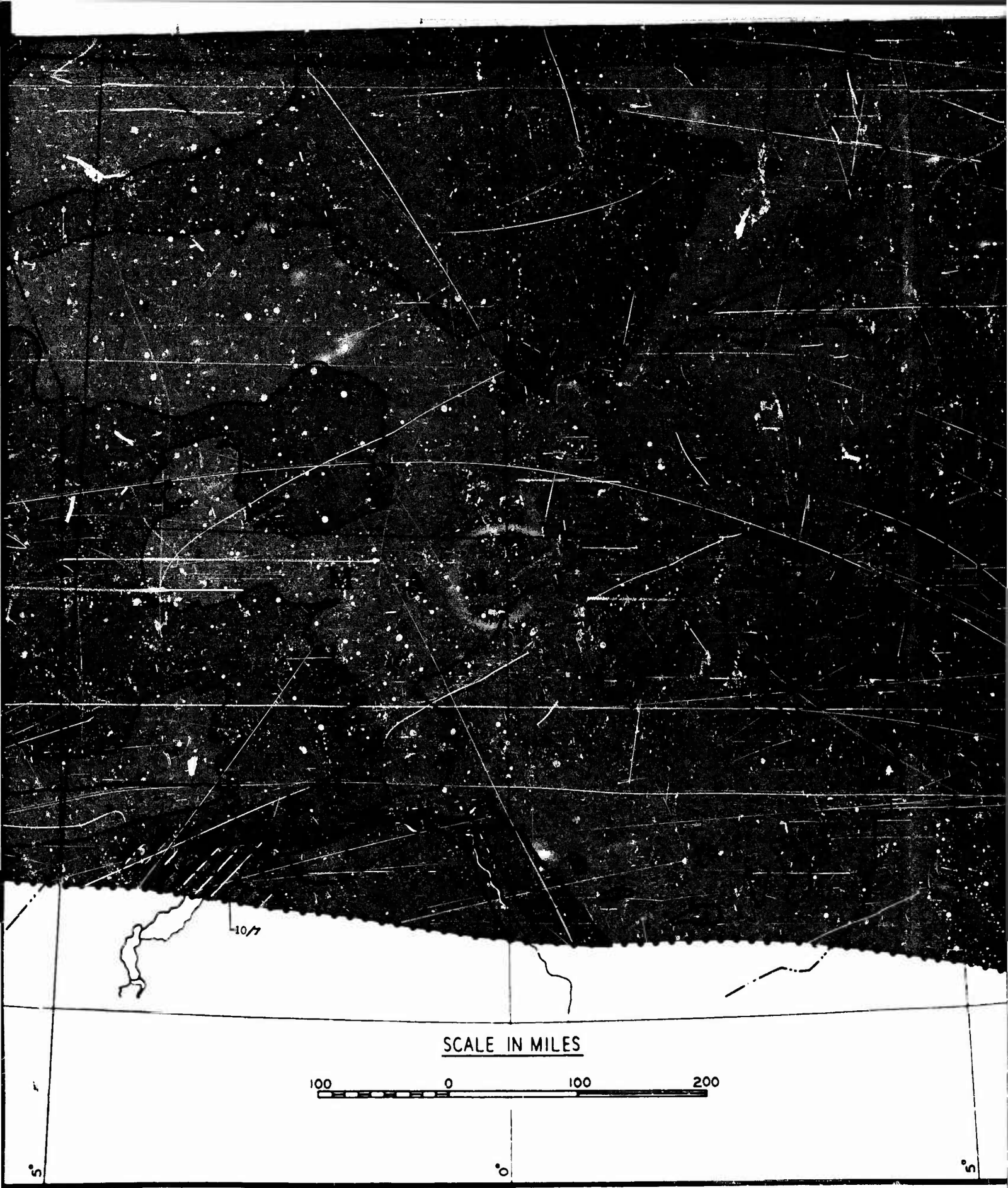
SCALE
0 5 10 MI.

YUMA TEST STATION

A

25°


ISLA CISNEROS
M A R
20°
3/10
15°
15°
10°
5°


10/7
SCALE IN MILES
100
0
100
200
5°
0°
5°


20°
15°
10°
5°

VEGETATION ANALOGS

LEGEND	
4	Number designates vegetation mapping unit.
2	Lightface number indicates that the unit is found at Yuma.
1	Boldface number indicates that the unit is not found at Yuma.
2/9	Indicates area of vegetation complex. Two definite vegetational types are present, but the scale of mapping precludes delineation. The areally predominant vegetation type appears first in the complex.

1		Highly Analogous	Unit found at Yuma.
0		Not Analogous	Unit not found at Yuma.

VEGETATION COMPLEXES:

Indicates the degree of analogy of the areally predominant vegetation type.

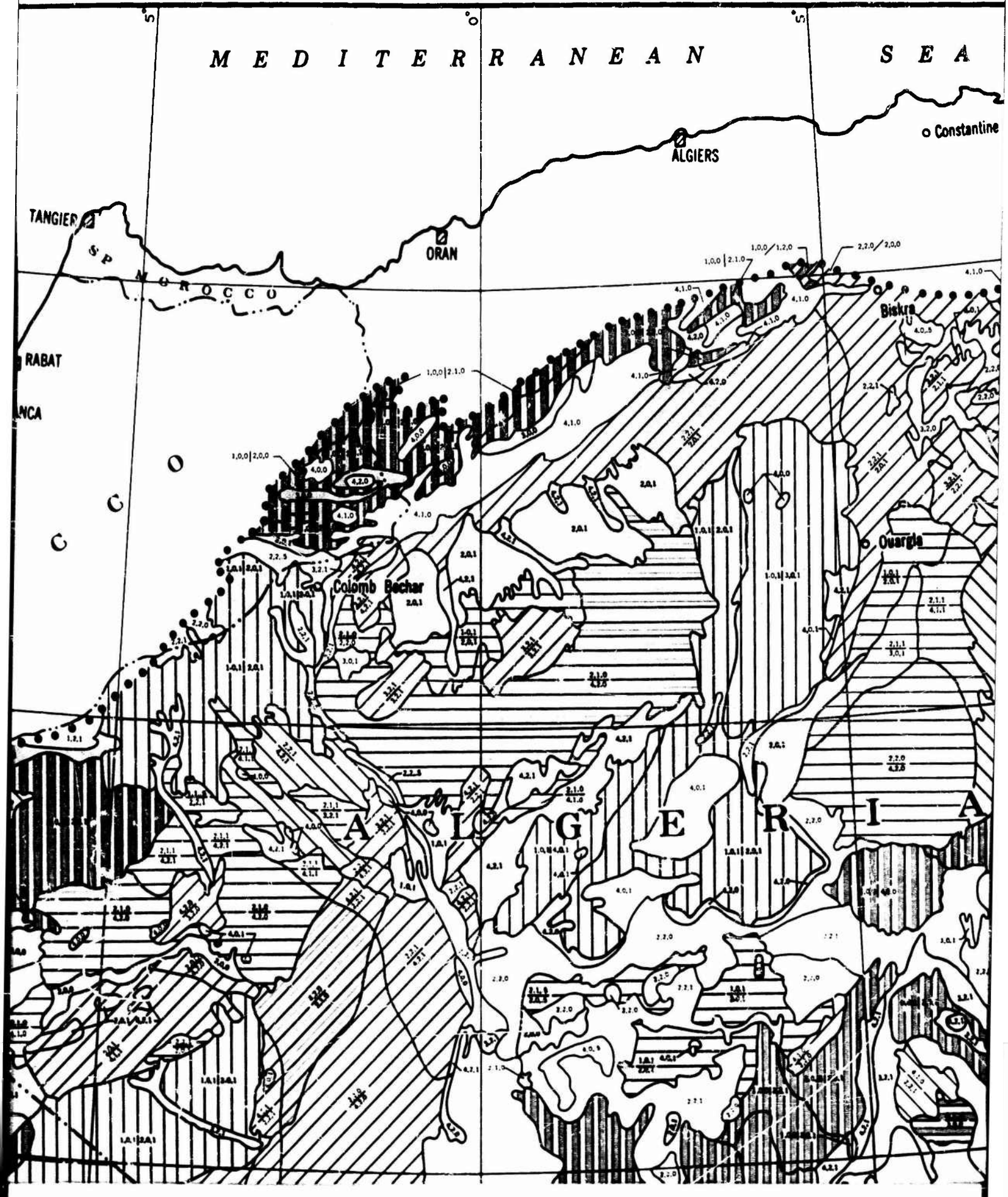
Indicates the degree of analogy of the areally subordinate vegetation type.

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT
VEGETATION ANALOGS

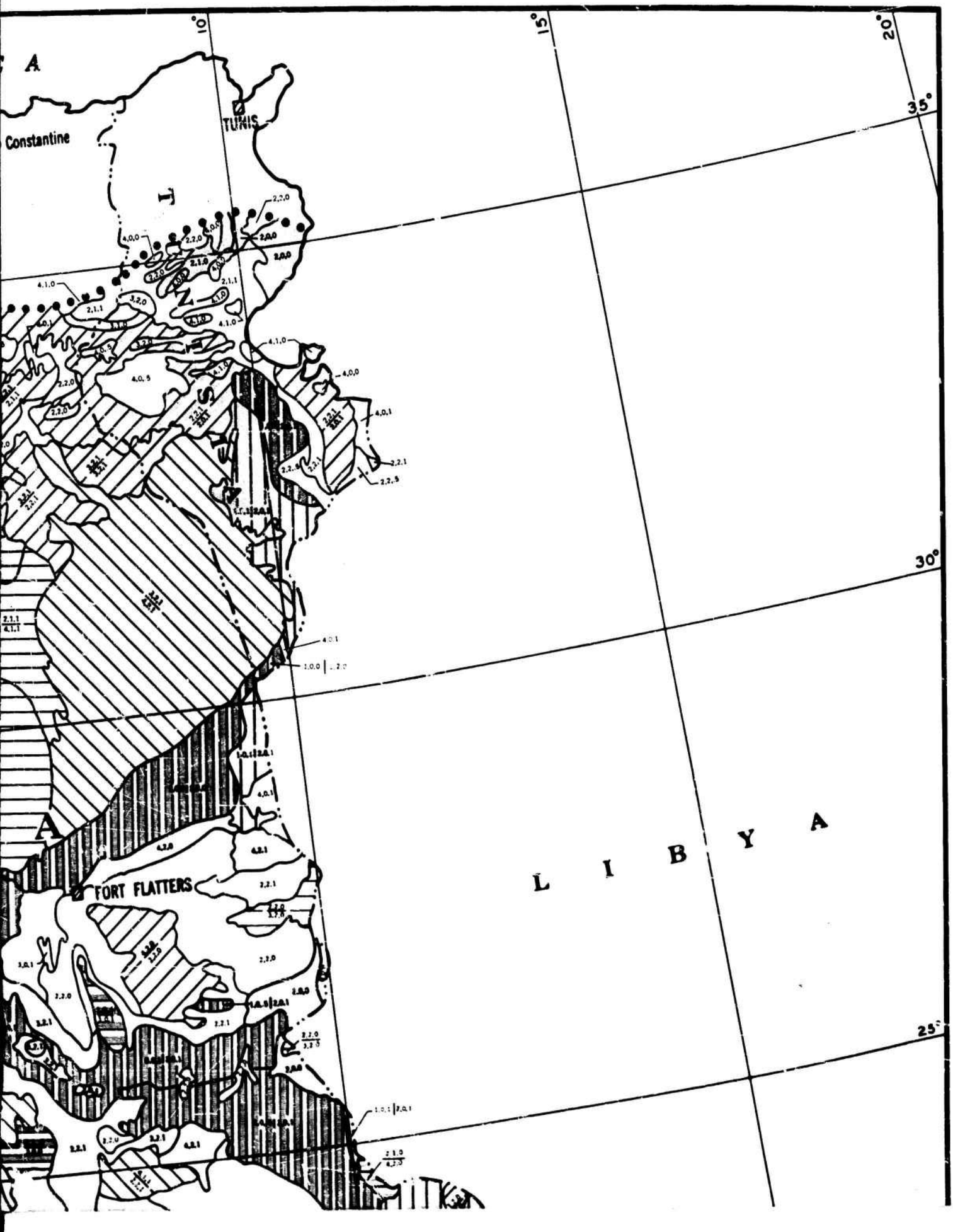
PLATE 12


20°
15°
10°
35°
30°
25°
ATLANTIC
OCEAN
TANG
RABAT
CASABLANCA
MARRAKECH
Mogador
VILLA CISNEROS

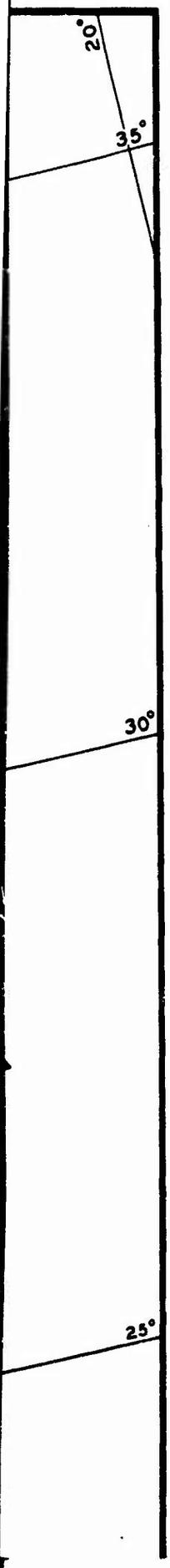
2


MEDITERRANEAN SEA
ALGIERS
Constantine
TANGIER
ORAN
SP MOROCCO
RABAT
Biskra
Ouargla
Colomb Bechar
ALGERIA

3



4



TERRAIN-TYPE ANALOGS

LEGEND

A terrain type is identified by a series of seven numbers, or number-letter symbols, each representing a value range or class of a geometry factor (plan-profile, slope occurrence, slope, relief), ground factor (soil type, soil consistency, or surface rock), and vegetation.

4,2,1

Areas delineated on the terrain-type analog map are designated by three digits. These numbers are determined by comparing the terrain type characterizing the area in Northwest Africa with the most similar terrain type found at Yuma. The numbers indicate, in sequence, the number of identical geometry, ground, and vegetation factor value ranges occurring in the Northwest African terrain type that are found in combination at Yuma. Thus, the series 4,2,1 found in Northwest Africa indicates that all seven terrain factor classes characterizing an area in Northwest Africa are found in combination at Yuma. (The actual terrain type can be determined by examining the geometry, ground, and vegetation analog maps or the individual factor maps.) The series 2,1,1 indicates that, when comparing the Northwest African terrain type with the most similar type found at Yuma, two of the four geometry factor classes, one of the two ground factor classes, and the vegetation class are found.

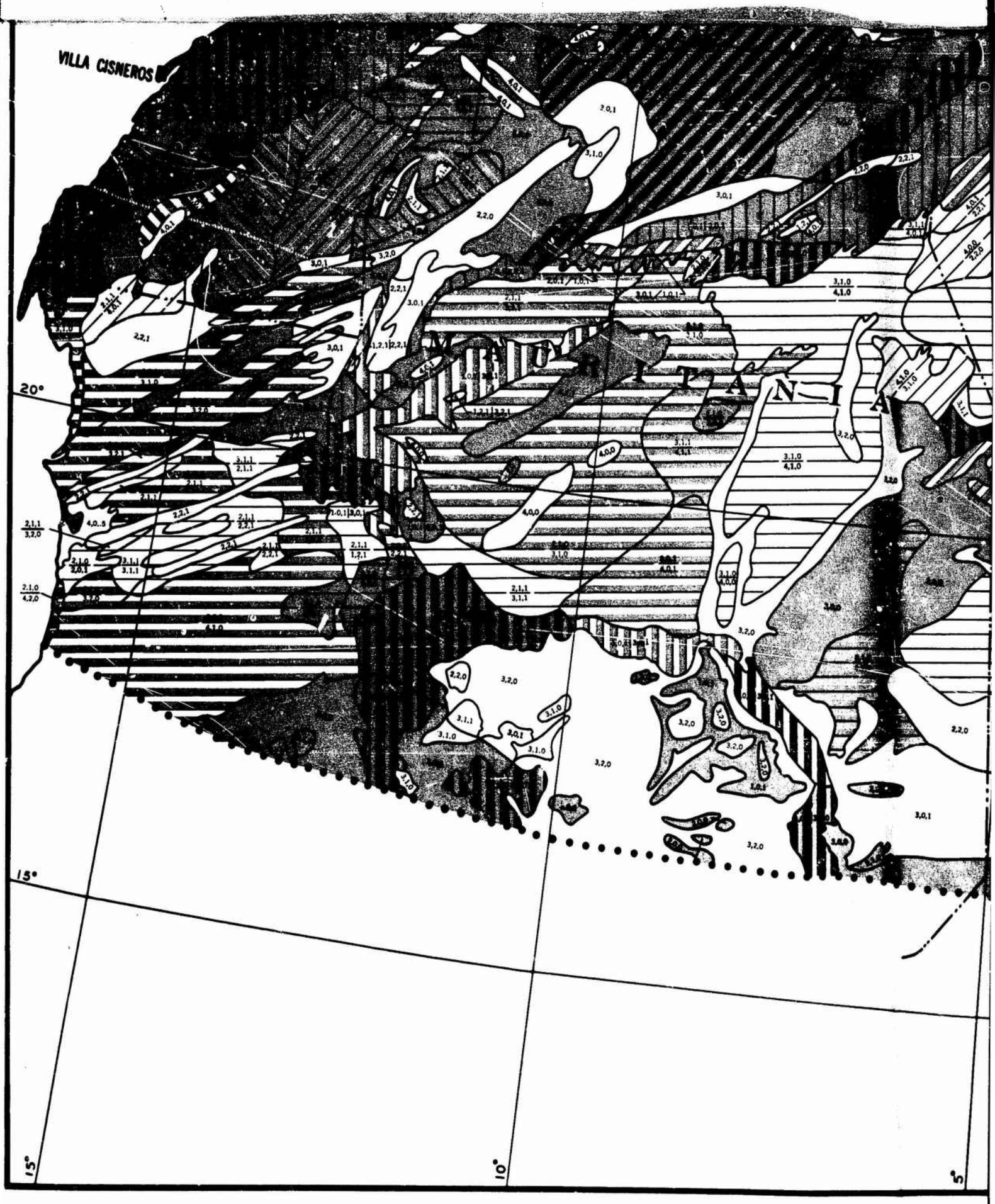
In selecting the most similar terrain type found at Yuma it is, of course, often possible to find two or three types having the same total number of factor classes in common with the Northwest African type under consideration. In this event, selection is based on the order in which the factors occur in the series or array. For example, the Northwest African terrain type 7,1,2,2 - 6,10 - 2 is compared with the Yuma type 7,1,1b,1 - 6,10 - 2 rather than with Yuma type 1L,4,2,2 - 6,10 - 2.

7
6.5
6 — Highly Analogous

5.5
5
4.5
4 — Moderately Analogous

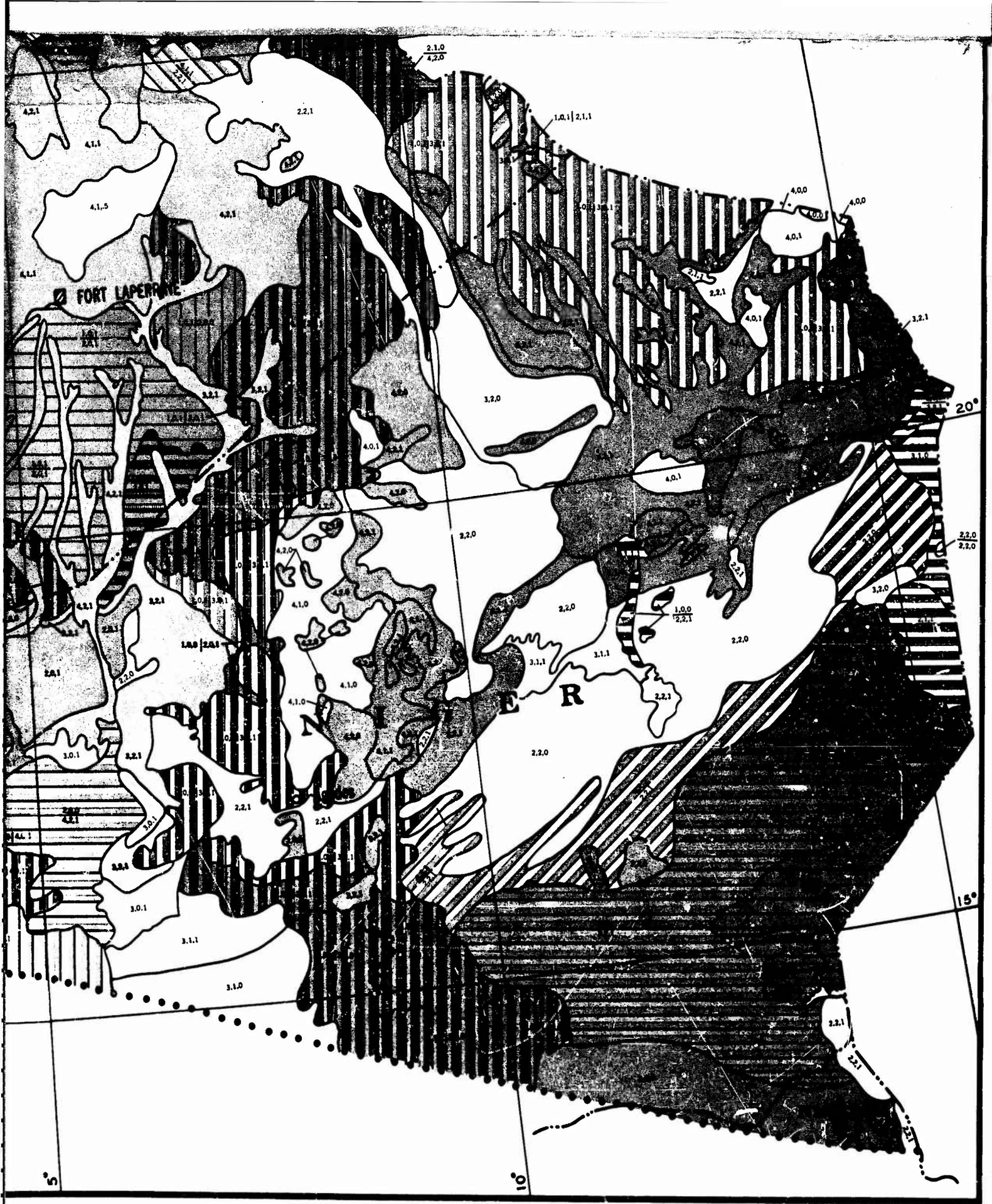
3.5
3
2.5
2 — Slightly Analogous

1.5
1
0.5 — Inappreciably Analogous



5


M
A
L
I
Tombouctou
Niger
River
SCALE IN MILES
100
0
100
200
5°
0°
5°


FORT LAPERRINE
NIGER
20°
15°
10°
5°

2.5
2 — Slightly Analogous

1.5
1
0.5 — Inappreciably Analogous

0 — Not Analogous

Total number of identical value ranges or classes of geometry, ground, and vegetation factors occurring in the most similar terrain type found at Yuma. Fractions result from mapping areal complexes of factor values.

TERRAIN TYPE COMPLEXES.

Degree of analogy of areally predominant terrain type.
Degree of analogy of areally subordinate terrain type.

Degree of analogy of gross terrain type.
Degree of analogy of terrain type characterizing component low or high.

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

TERRAIN - TYPE ANALOGS

PLATE 13

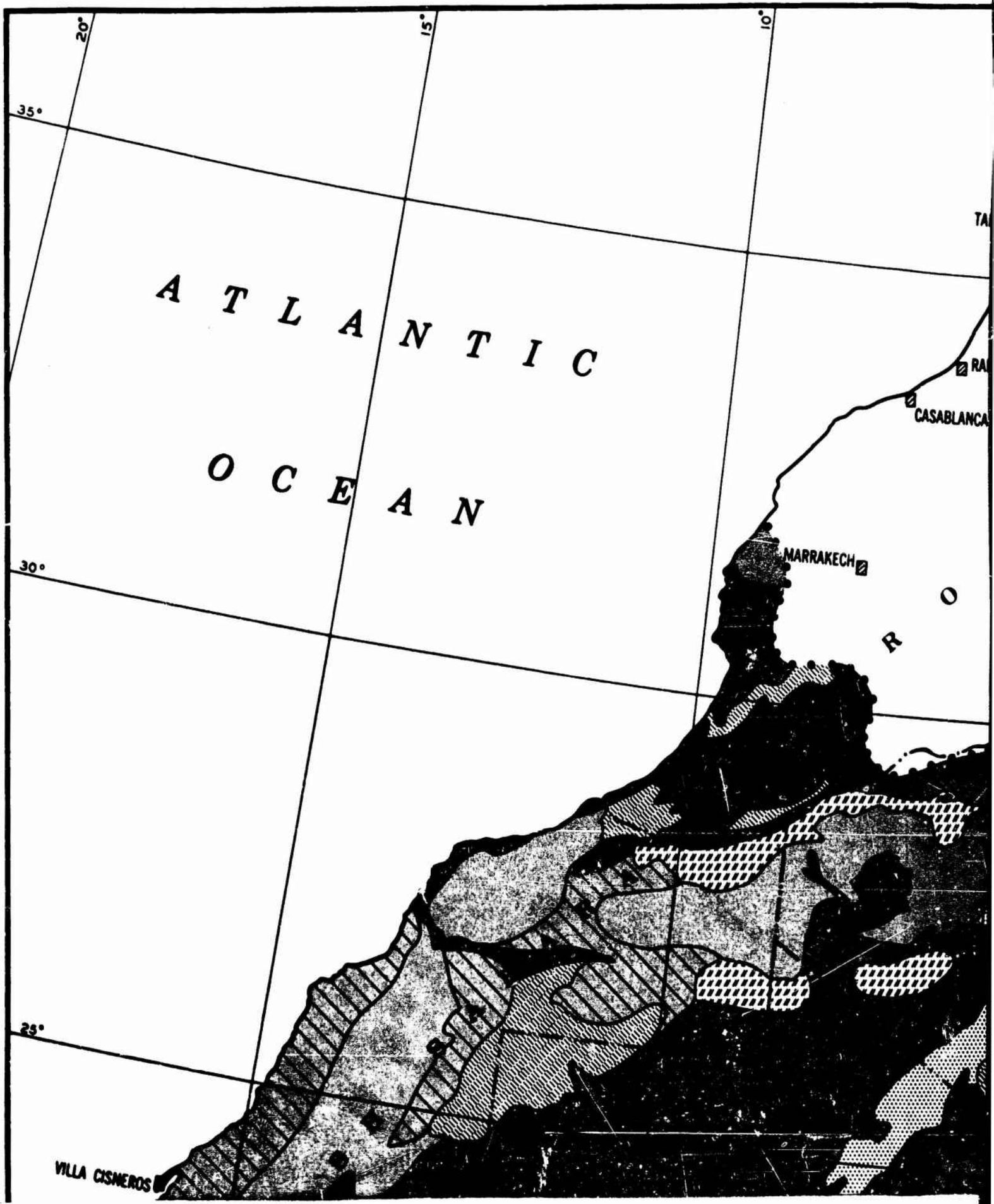
ANALOGS OF YUMA TERRAIN

IN THE NORTHWEST AFRICAN DESERT

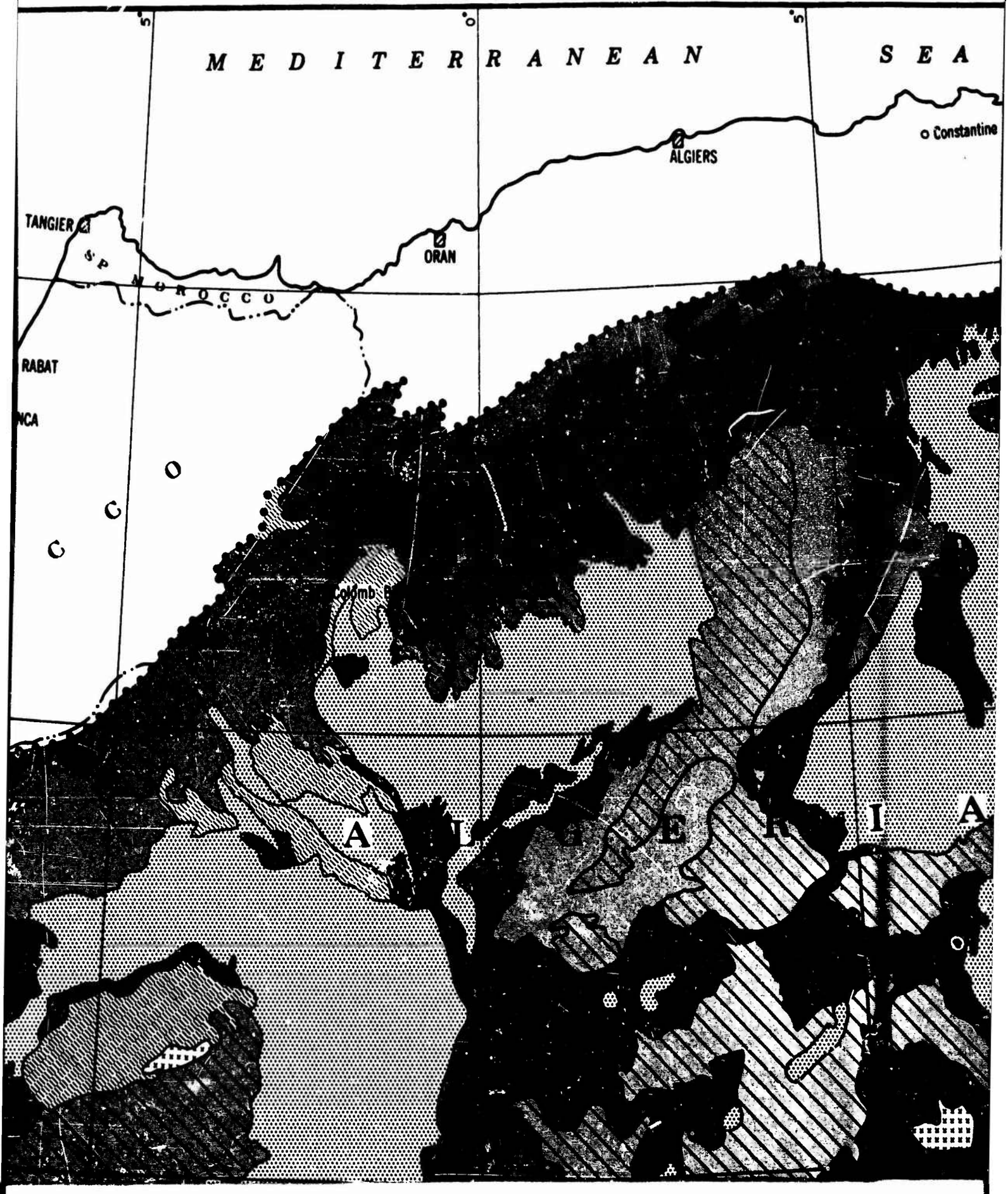
SECTION II:

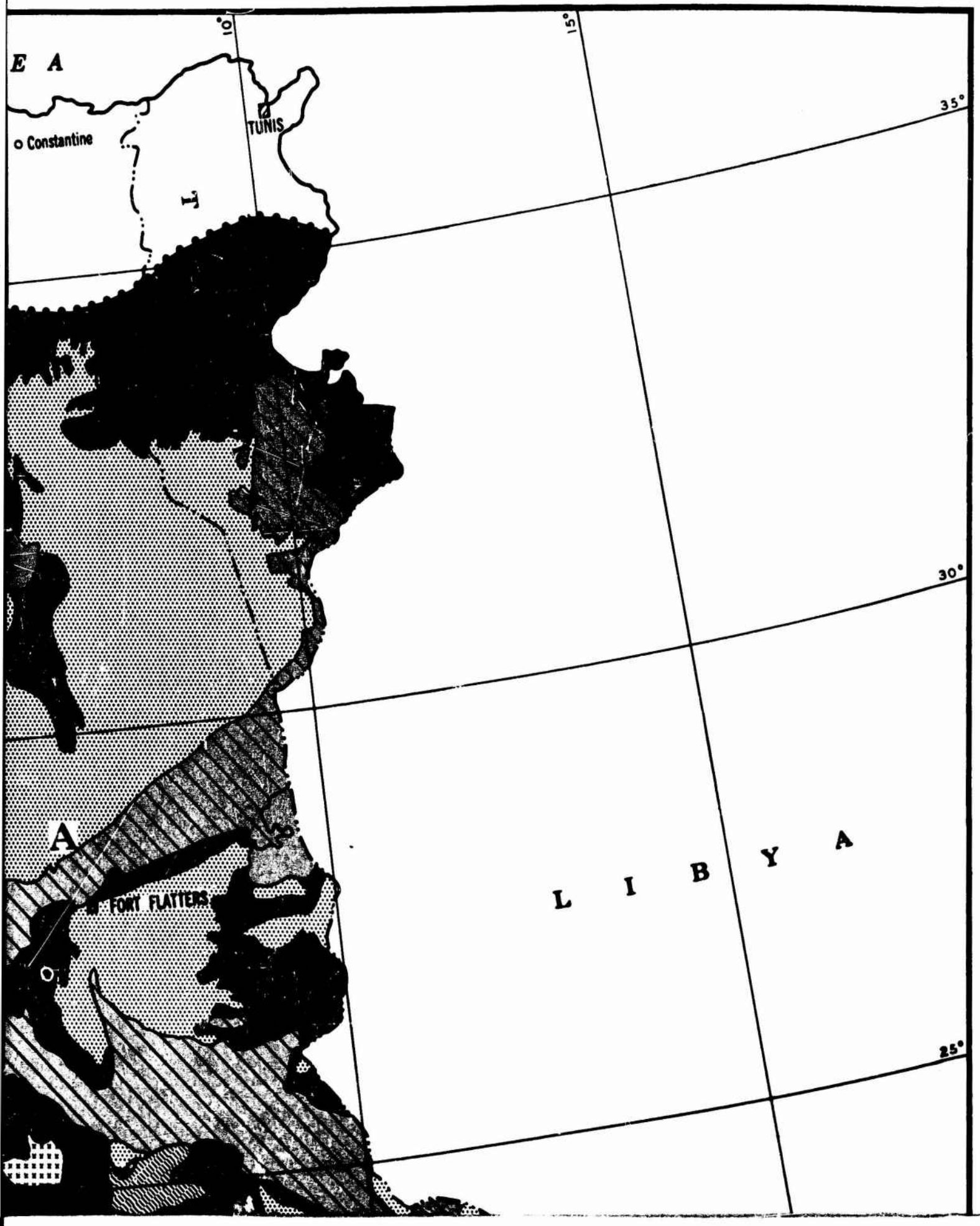
SUPPLEMENTAL MAPS

AND TABULATIONS

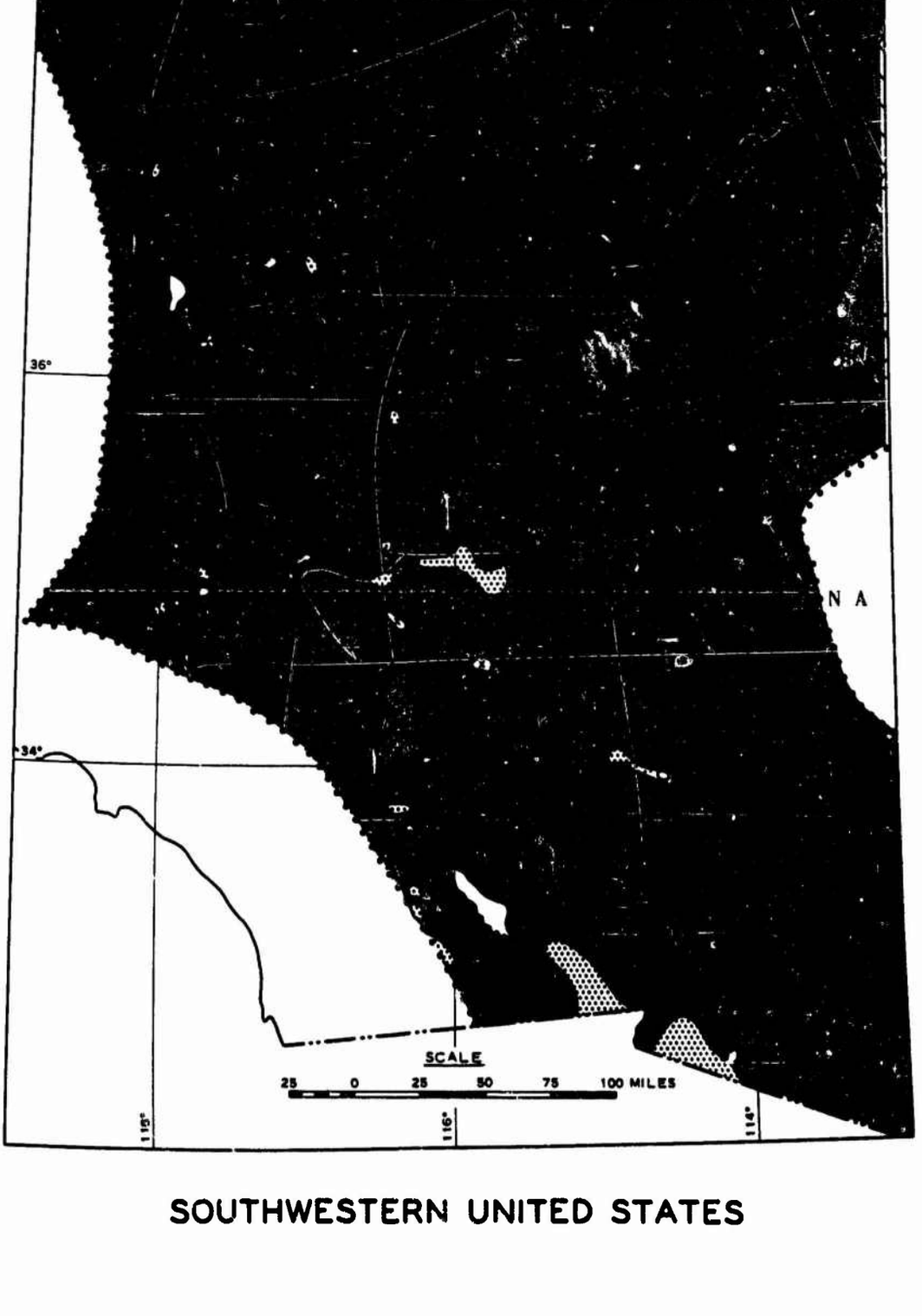

20°
15°
10°
35°
ATLANTIC
OCEAN
CASABLANCA
MARRAKECH
30°
25°
VILLA CISNEROS

2


MEDITERRANEAN SEA
ALGIERS
Constantine
TANGIER
ORAN
SPANISH MOROCCO
RABAT
Colomb
ALGERIA


E A
Constantine
TUNIS
10°
15°
35°
30°
25°
A
FORT FLATTERS
L I B Y A

4



SOUTHWESTERN UNITED STATES

PHYSIOGRAPHY

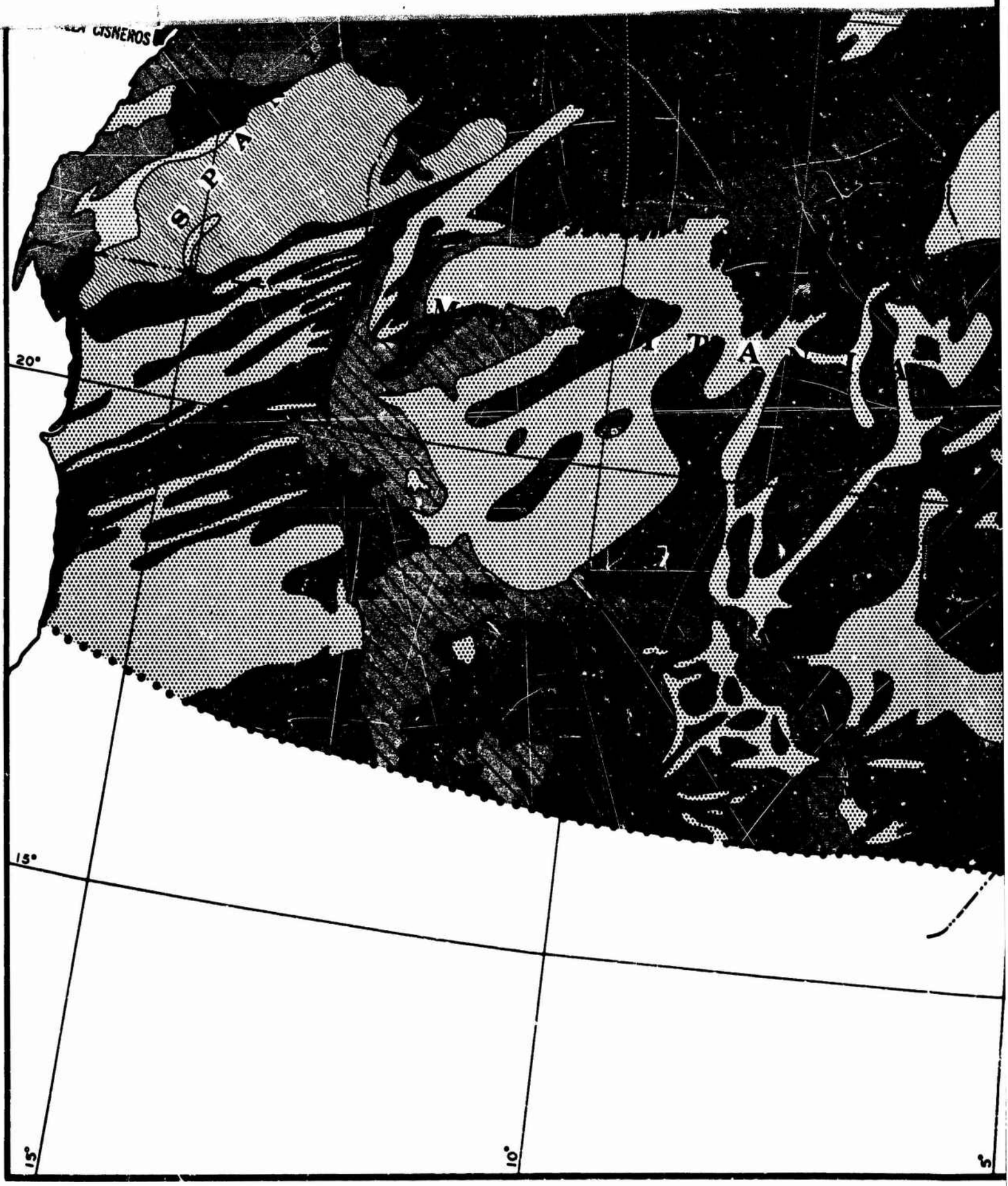
MOUNTAINS: Masses of land, in which summit areas are small in proportion to basal dimensions, rising more than 1000 feet above the surrounding terrain. The characteristic slope is declivitous or steep.*

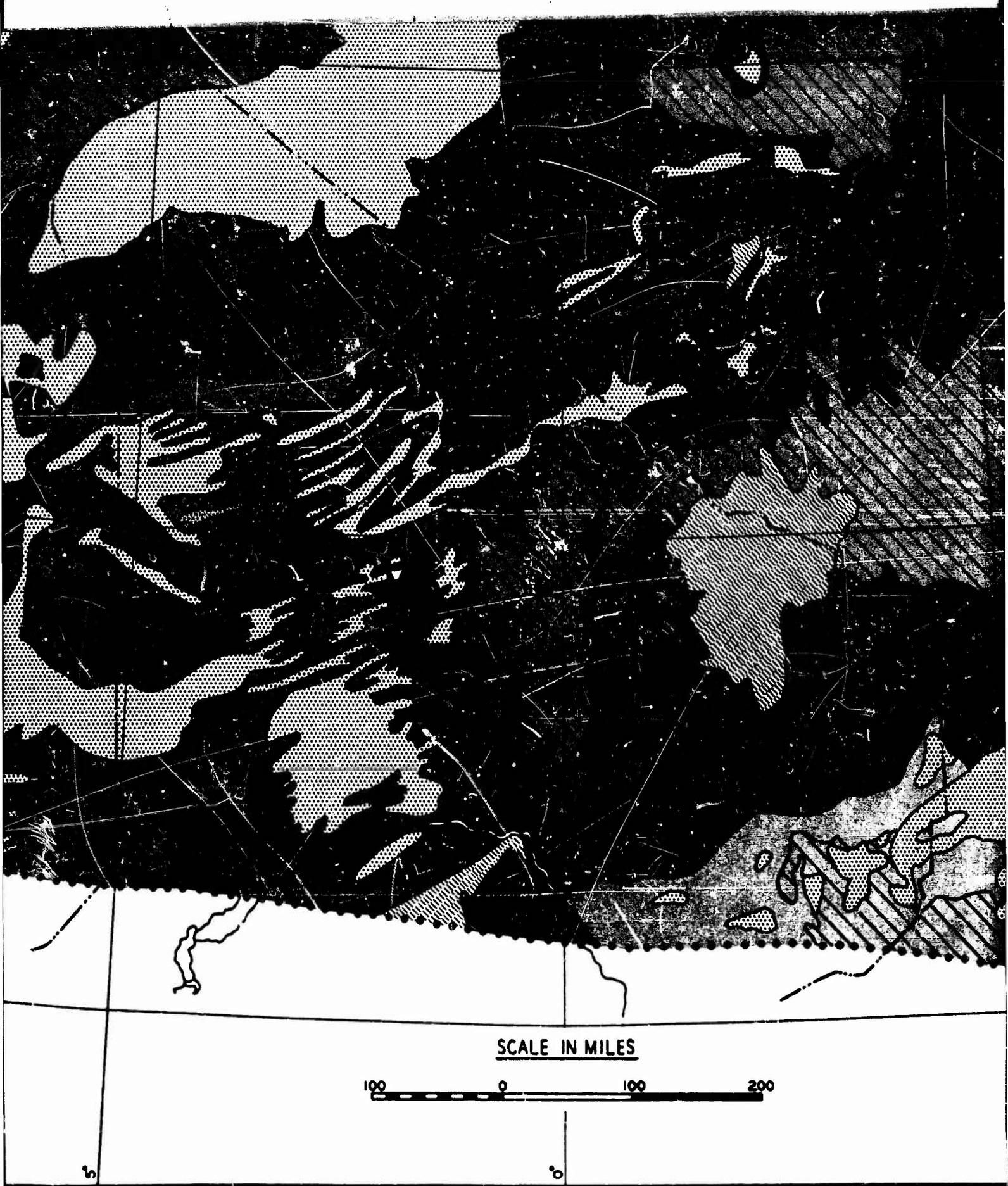
Massive Mountains: Extensive multiple-peaked mountain masses characterized by either a high centrally located core or an elongate crest which rises more than 5000 feet above the surrounding terrain.

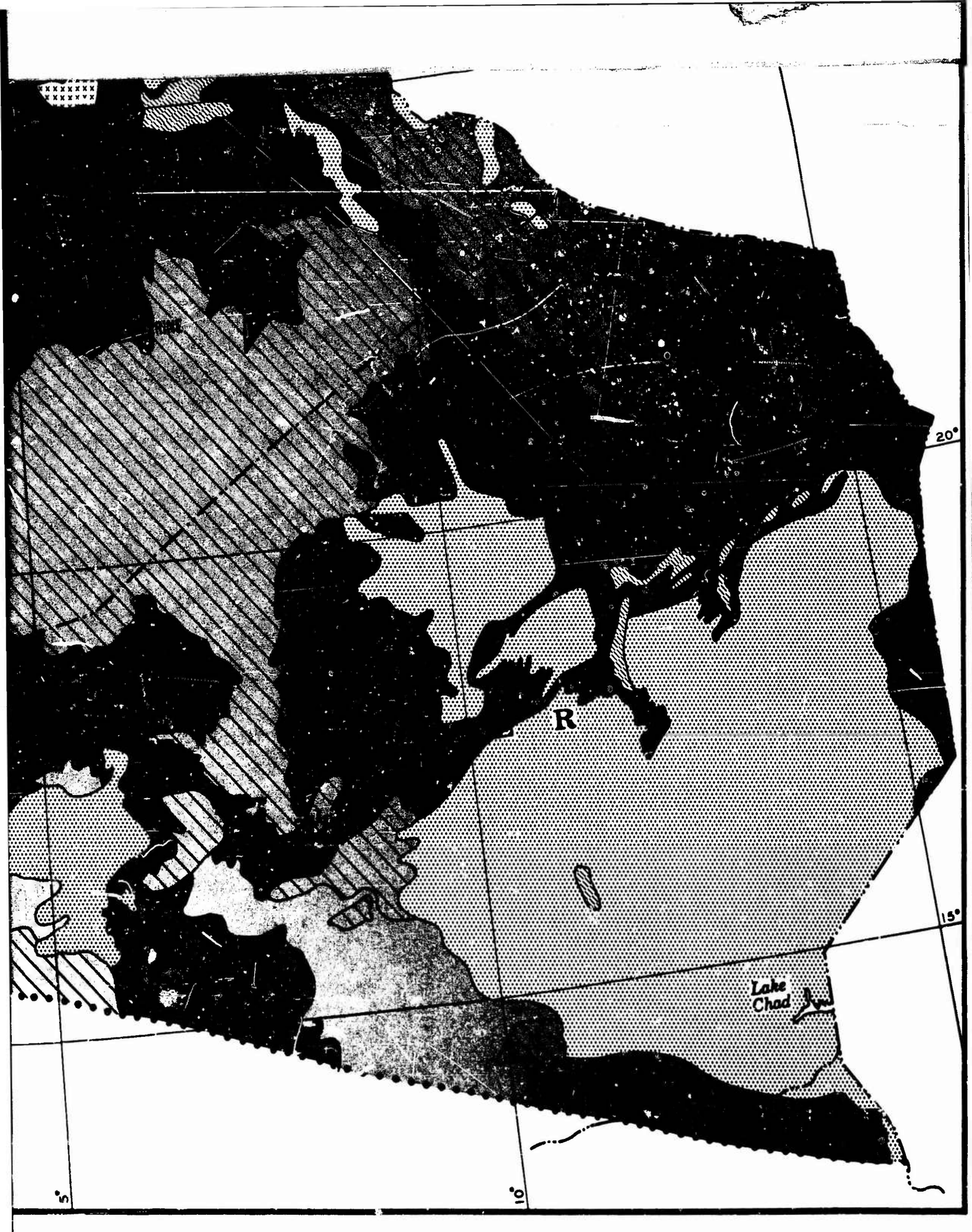
1 Ranges: Elongate belts of massive mountains.

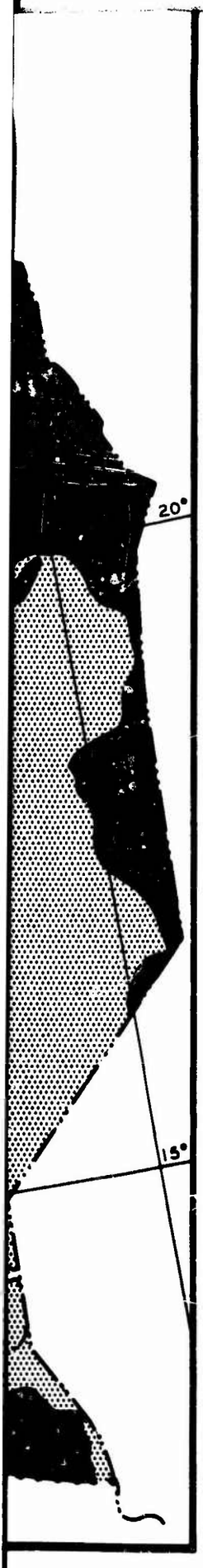
2 Massifs: Roughly circular aggregation of massive mountains.

Ridge Mountains: Continuous ridges of aligned crestal peaks typically rising less than 5000 feet


CISNEROS
SPAIN
20°
15°
15°
10°
5°


SCALE IN MILES
100
0
100
200


20°
15°
10°
5°
R
Lake
Chad



1 Ranges. Elongate belts of massive mountains.

2 Massifs: Roughly circular aggregation of massive mountains.

Ridge Mountains: Continuous ridges of aligned crestal peaks typically rising less than 5000 feet above the surrounding terrain.

3 Single Ridge: Single, isolated mountain ridge.

4 Parallel Ridges: A series of roughly parallel ridges; some peaks may rise more than 5000 feet above narrow, intervening valleys.

Heterogeneous Mountains: Mountain masses, commonly separated by regions of other terrain types, cover substantially more than 50 per cent of the total area. Any area so mapped is not characterized by either a high centrally located core or an elongate crest.

5 Peaks and Groups of Peaks: The mountain masses consist predominantly of peaks and groups of peaks.

6 Random Ridges: The mountain masses consist predominantly of discontinuous, randomly oriented ridges.

PLAIN AND MOUNTAIN COMPLEX: Mountains, separated by plains with occasional hills, cover less than 50 per cent of the total area.

7 Isolated Peaks and Ridges: The mountain masses consist predominantly of peaks and randomly oriented discontinuous ridges.

8 Basin and Range: The mountain masses consist predominantly of roughly parallel ridges.

HILL LANDS: Areas characterized by prominences of small summit area, with characteristic slopes gentle to steep, rising less than 1000 feet above the surrounding terrain. Plains regions between hills may range as high as 75 per cent of the total area.

9 Parallel Hills: Prominences consist predominantly of parallel elongate hills with characteristic slopes moderate to steep.

10 Random Hills: Prominences consist predominantly of randomly distributed hills with characteristic slopes moderate to steep.

11 Volcanics: Prominences consist predominantly of randomly distributed conical and irregularly shaped hill forms. Inter-hill areas characterized by rough surface of angular to jagged cobbles and blocks. Slopes may range from gentle to precipitous. In rare instances, conical hills may be absent.

12 Sand Dunes: Prominences, consisting chiefly of eolian sand, commonly (but not invariably) change shape and position rapidly. Areas characterized by a total lack of organized drainage lines and moderate to steep slopes.

13 PLATEAUS: Elevated masses of land characterized by extensive, more or less flat-lying summit areas bounded on one or more sides by scarps. (Scarps† are indicated on maps by a toothed line; all other boundaries are more or less gradational.) Dissected plateaus are indicated (by a lined overprint) where less than 85 per cent of the original surface remains.

PLAINS: Extensive tracts of land with characteristic slopes flat to gentle. Less than 25 per cent of the surface is occupied by hills, and local relief within the plains seldom exceeds 50 feet. (Because of the transitional nature of most plains types, boundary lines are often difficult to establish and in many cases are quite arbitrary.)

14 Alluvial Plains: Floodplains, terraces, and subaerial deltas of major streams.

15 Coastal Plains: Plains bordering the sea and extending inland to the nearest elevated land, or to a gradational border with another plains type.

16 Depression Plains: Low-lying plains of interior drainage bounded on two or more sides by scarps or steep mountain fronts, and commonly characterized by a centrally located brackish or saline lake, generally but not invariably ephemeral.

17 Desert Plains: Interior plains not readily classifiable as alluvial, coastal, or depression plains. These plains are often formed or significantly modified by eolian deposition or erosion.

* Slope classification: flat = 0 to 2 degrees, gentle = 2 to 6 degrees, moderate = 6 to 14 degrees, declivitous = 14 to 26.5 degrees, steep = 26.5 to 45 degrees, precipitous = greater than 45 degrees.

† A scarp is defined as a more or less continuous precipitous slope exhibiting more than 100 feet of relief. Important scarps are indicated in plates 3 and 4.

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT
PHYSIOGRAPHY

PLATE 14

MOUNTAINS:

Mountains are masses of land which exhibit summit areas that are small in proportion to basal dimension and rise more than 1000 ft above the surrounding terrain. Included under mountains are plain and mountain complexes. These complexes consist of mountains, which cover less than 50 percent of the total area, separated by plains with occasional hills. All types of mountains were mapped in the Northwest African Desert except ridge mountains and basin and range complexes. Mountains occupy approximately 5 percent of the study area. Probably the best known mountainous region in Northwest Africa is the Ahaggar located in the east central part of the study area. This region consists of massifs and peaks and groups of peaks which have been exposed through erosional processes. The deep, entrenched valleys of this desolate region contribute their part to the ruggedness of the landscape. Although most of the Ahaggar lies between 3000 and 7000 ft above sea level, this region rises in elevation from 2000 ft along the eastern limit to almost 10,000 ft in the central massif where the two highest peaks, Mt. Tahat (9852 ft) and Mt. Illaman (9175 ft), occur.

A southwestern projection of the Ahaggar in Mali is the Adrar des Iforas, a highly eroded crystalline area. Because the total area referred to as Adrar des Iforas does not meet the established criteria for mountains, only the western part of the region is included in the mountain category. This area consists predominantly of peaks and groups of peaks. These mountains rise above the Tilemsi valley on the west and merge with hill lands on the east. The highest elevation within these mountains approaches 3000 ft above sea level.

East of the Adrar des Iforas and southeast of the Ahaggar are the Aïr Mountains a counterpart of

Francis Rodd 19 †

M-1. The Agellal Mountain rising above the adjoining valley in northern Aïr. The village of Agellal is shown in the foreground. At N18°37', E8°35'

Institut Ge

M-2. An aerial view of the Central Ahag canic mountainous area in Southern Alge location N23°30', E5°30

PHYSIOGRAPHY: DESCRIPTIONS

the former and another projection of the latter. The Aïr Mountains rise abruptly from the surrounding lands and extend for about 250 miles from north to south and 150 miles at their widest point east to west. Several subsidiary massifs may be distinguished, all of which lie between 3000 and 5000 ft in elevation.

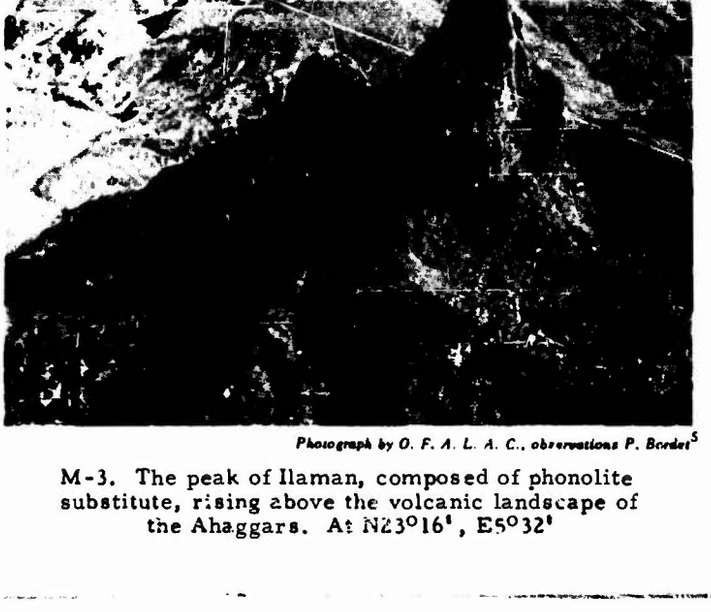
The Saharan Atlas forms a discontinuous band of ridges across the northern part of the study area. These mountains stretch across Algeria and extend for short distances into Morocco and Tunisia, respectively. The Saharan Atlas, with its southwest-northeast trend, ranges in elevation from 3000 to 5000 ft, although some ridges spotted along the western and central parts reach elevations from 5000 to 6500 ft above sea level.

The remaining mountains in Northwest Africa occur in Morocco. They include the western extremity of the High or Haut Atlas and the Anti-Atlas ranges. These massive mountain ranges, separated by the Sous plain, join east of the study area to form a single range of mountains. Deeply dissected by many gorges, the Haut Atlas lies between 1000 and 6000 ft above sea level in the study area; however, they continue to rise eastward and reach an elevation of greater than 13,000 ft. The Anti-Atlas also are highly dissected and lie between elevations of 1000 to 8000 ft with highest point attaining an elevation of 8302 ft.

Igneous, metamorphic rocks are the chief constituents of the mountain masses in the study area. Sedimentary rocks form the predominant rock type in the Saharan Atlas and are either absent or occupy only a minor amount of the other mountainous areas. Relief varies from 50 to a few thousand feet, although it is predominantly on the order of 150 to 500 ft.

Institut Géographique National, France[16]

al Ahaggar, a vast volrn Algeria. Approximate , E5°30'



Photograph by O. F. A. L. A. C., observations P. Border[5]

M-3. The peak of Ilaman, composed of phonolite substitute, rising above the volcanic landscape of the Ahaggars. At N23°16', E5°32'

NS AND PHOTOGRAPHS

HILL LANDS:

Hill lands are areas characterized by prominences of small summit area, with gentle to steep slopes that rise less than 1000 ft above the surrounding terrain. Areas mapped as hill lands may be individual hill masses or may include hills separated by plains that occupy as much as 75 percent of the area. Sand dunes, volcanics, and random and parallel hills occupy 29 percent of the Northwest African Desert.

Vast regions of sand dunes referred to as ergs occur throughout the study area. In northeast Algeria is the Grand Erg Oriental, also called the Erg of Irharhar, where dune types including longitudinal, complex, and massifs occur. In the west central part of this region, long, narrow, dune-free corridors or gassi occur which are used as routes of transportation to traverse this region. Heights of the dunes above the surrounding terrain range from tens of feet up to 800 ft.

West of the Grand Erg Oriental and separated by the Plateau El Gantara is the Grand Erg Occidental which is somewhat smaller in area than its western counterpart. This region is also characterized by long, parallel dunes, especially in the central part of the erg. These longitudinal dunes are separated by troughs which are not as extensive in length as those found in the Oriental Erg. The corridors are interrupted by transverse dunes which are so frequent in certain parts of the erg as to give a honeycomb appearance to the topography. Complex and barchan dunes are also types found within this erg.

The Ergs Chech, Iguidi, and Er Raoui form a horseshoe-shaped area of dunes that falls within Algeria, Mauritania, and Mali. The predominant dune types in this region are longitudinal, or sief, and

complex dunes
Northwest Afri
solidated hill a
clude the Irrar
and the Ouarar
bilized or fixe
jacent to the T

Randon
similar in app
hill land regio
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rial. Unconso
Sedimentary r
dom hills are
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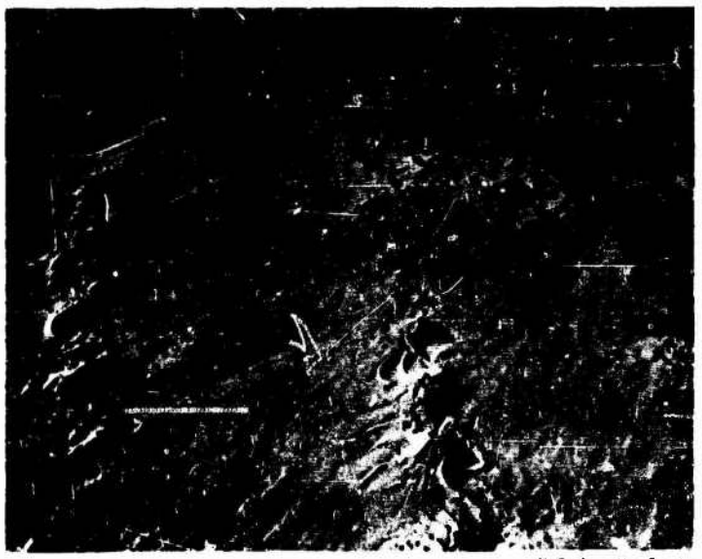


U. S. Army Map Service

H-1. Complex longitudinal dunes in the Grand Erg Occidental. Location N29°10', W1°21'

Photograph by A

H-2. A dune field composed of individual barchan intersecting barchan dunes. The oasis at In Salah in the background. At N27°13', E2°28'

complex dunes separated by gassi in which old drainage channels are evident. The largest dune area in Northwest Africa is the Tenere, an area consisting predominantly of sief dunes. Several isolated consolidated hill areas occur within this sea of sand. The remaining active dune areas in the study area include the Irrarene Dunes and the Erg of Admer in Algeria, the Arouana Dunes and Azouad Sands in Mali, and the Ouarane Sands, the Makteir Dunes, and other scattered areas in the Ed Djouf in Mauritania. Stabilized or fixed dune areas occur between the coast and the plateau in southwestern Mauritania and adjacent to the Talak Basin in Niger.

Random consolidated hills are included in regions of the Ahaggar and Adrar des Iforas which are similar in appearance to the adjacent mountainous region except for the lower relief. The El Tiris, a hill land region in southern Spanish Sahara, is characterized by isolated hills or chains of hills surrounded by monotonous flat plains. South of the Wadi Draa in Spanish Sahara, Algeria, and Mauritania are folded rock strata in the form of parallel ridge hills separated by alluvial basins. Volcanics have been mapped in the Eguere and in the eastern part of El Eglab in Algeria.

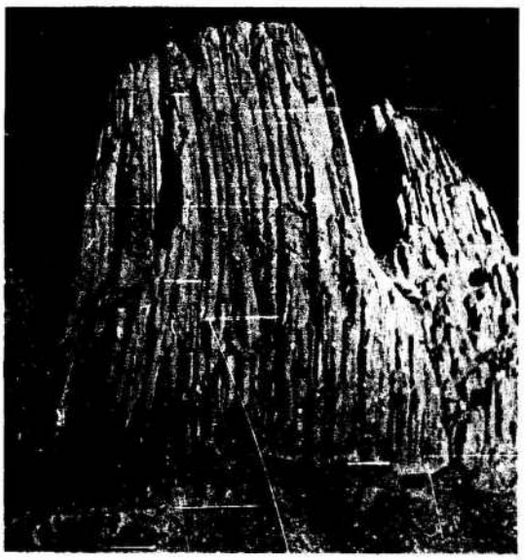
The hill lands in the Northwest African Desert vary from unconsolidated to consolidated material. Unconsolidated material is restricted to the sand dune areas and the plains included in this unit. Sedimentary rocks compose the parallel hills and extrusive igneous rocks form the volcanics. The random hills are predominantly of igneous rocks with minor amounts of sedimentary rocks. Relief within the hill lands varies from 50 to 800 ft, and vegetation cover can usually be described as barren to scattered.

Photograph by Aviation militaire[5]

...composed of individual barchans and ...n dunes. The oasis at In Salah is shown ...kground. At N27°13', E2°28'

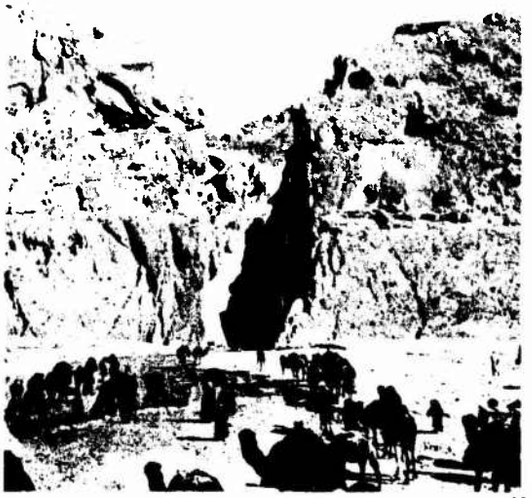
Photograph by Capot-Rey[5]

H-3. An aerial view of ridge hills in the foreground and pyramidally shaped dunes in the background. The floodplain of the Wadi Saoura separates these distinct hill types. Location N29°31', W1°33'



P. Bordet[9]

M-4. West face of Tidjemayene, a phonolite peak in the Ahaggan that rises 650 ft above the surrounding terrain. Approximate location N23°25', E6°20'



M. O. Williams[25]

M-5. The Seldja gorge forming a gateway through the mountains to the Sahara in western Tunisia. Location N34°51', E8°36'

M-6. Bord th

Photograph by C. Bourdelon, Mission du Hoggar[5]

M-8. Disintegration of granite at the summit of Tefedest. Boulders of varying forms have been clefted and sculptured through mechanical and chemical weathering. At N25°5', E5°25'

M-9. Looking across the Wadi Tihaliou mass rising above the dry streambed. N23°10', E8°15'

† Raised numbers refer to similarly numbered entries in the photographic bibliography at the end of volume I of th

the Anaggars. At N23°16', E5°32'

Service Photographique du C[t] général[9]

M-6. Terrain crossed by the road between Bordj and Cahiba. In the left background is the Djebel Ksaum. At N34°52', E4°54'

Photograph by Aviation militaire, observations P. Bordet[5]

M-7. A recent basaltic crater (center foreground) in the Ahaggars. Immediately behind and to the left of the crater lies a granite massif. The dark area behind the crater and massif is a ridge of lava. Location N23°55', E5°55'

Georg Gerster[11]

di Tihaliouine at a mountain
reambed. Location
, E8°15'

P. Bordet[9]

M-10. The dome of Tesnou, a granite mass which forms part of the Ahaggars. Location N24°41', E4°38'

ume I of this report.

intersecting barchan dunes. The oasis at in
in the background. At N27°13', E2

J. Saigot[9]

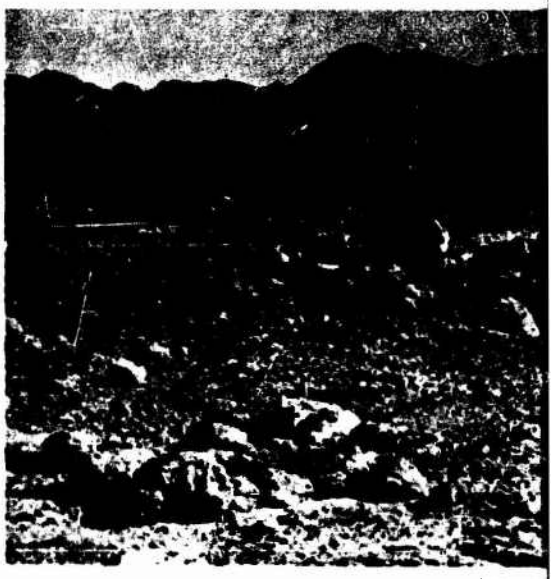
H-4. Dune massifs separated by low dunes in the Grand Erg Oriental. Note the sparse vegetation which constitutes the basis of grazing lands. Location N32°21', E6°51'

H-5. Ripple sand surface in Spanish Sahara with complex dunes in the background. Exact location unknown

H-6. A go
and fan fo
Algeria. T
dry strean
the pho

Aerotec[9]

H-8. Sandstone hills with the Erg el Atchane in the background. The drainage net shown converges toward the Sebka el Melah. Location N29°23', W1°26'



Institute

H-9. Rock outcrops on a plain bordering a
solidated hills. At N21°38', W14°

dunes. The oasis at In Salah is shown round. At N27°13', E2°28'

pyramidally shaped dunes in the background. The flood-plain of the Wadi Saoura separates these distinct hill types. Location N29°31', W1°33'

Institut Géographique National, France[14]

H-6. A good example of an alluvial apron and fan formed at the base of a hill in Algeria. These landforms border a wide, dry streambed that appears in the center of the photograph. At N28°27', W9°10'

Instituto de Estudios Africanos[13]

H-7. Gabbro weathering into splinter-like particles along rectangular fractures in Southern Spanish Sahara. At N21°38', W14°51'

Instituto de Estudios Africanos[13]

n a plain bordering a range of con-lls. At N21°38', W14°10'

ANALOGS OF YUMA TERRAIN IN THE NORTHWEST AFRICAN DESERT

PHYSIOGRAPHY

DESCRIPTIONS AND PHOTOGRAPHS

PLATE 15

PLATEAUS:

Plateaus are elevated masses of land characterized by extensive, more or less flat-lying summit areas bounded on one or more sides by scarps. Dissected plateaus are areas wherein less than 85 percent of the original flat-lying summit area remains. Plateaus occupy approximately 28 percent of the Northwest African Desert and almost completely encircle the study area. A series of dissected plateaus, referred to as tassilis, which are separated by wide wadi systems form a discontinuous band around the Ahaggar Mountains. Occupying the eastern part of this circular belt is the Tassili n' Ajjer, a rugged sandstone region characterized by steep-sided, sand-choked wadis. Lying between Ahaggar Mountains and the Adrar des Iforas and the Air Mountains is the Tassili Oua-n-Ahaggar, a maturely dissected plateau with isolated hills and wide, dry streambeds. The northwest part of this plateau band is the Asedjrad, Ahenet, and Mouydir plateaus which are similar in many respects to their counterparts in the east.

East, south, and west of the Grand Erg Oriental in Algeria are the El Gantara Tademait, Tinrhert, and Marth plateaus. These plateaus are more often referred to as hamadas, a term signifying a barren rocky surface which describes these areas. These great expanses of rocky limestone wasteland for the most part are dissected except for the parts of the Tademait and El Gantara where the frequency of the streambeds is reduced. Lying between the northern limit of the study area and the Saharan Atlas is a part of the Haut Plateau. This region is marked by an undulating surface that is broken by an occasional ridge and enclosed basins or chotts where lakes form after rains.

West of the Haut Plateau are a series of hamadas that extend to the Atlantic Ocean and then south

Photograph by Aviation militaire[5]

PL-1. A meandering valley carved in a sandstone plateau near Arak. Aeolian action has accentuated the irregular surface and the cuts along the edge of the plateau. In the background is a desert plain with scattered hills.
Approximate location N25°17', E5°21'

PL-2. A view of the escarpment t
the Draa Plateau in the vicinity of
mate location N29°17

PHYSIOGRAPHY: DESCRIPTION

through Spanish Sahara to the vicinity of Port Etienne in Mauritania. In Algeria these plateaus are the Hamadas Dra, Guir, Du Daoura, and Tounassine. The surfaces of these plateaus are similar and vary from a relatively level rocky surface to a highly dissected landscape where streams have sculptured wide, deep valleys. The regional slope of the Algerian and eastern Spanish Sahara plateaus is in a southerly direction toward the central basin of the study area. The western limit of the plateaus in Spanish Sahara is marked by discontinuous scarps facing the Atlantic Ocean.

In western and southwestern Mauritania lie the sandstone plateaus of Adrar, Tagant, Tichitt, and Oulata. The western and/or southern limits of these plateaus terminate an almost continuous escarpment which rises more than 100 ft above the lower lying desert plains. The northern and eastern limits are not as well defined and grade into adjoining sandy desert plains. Intermittent stream valleys occur frequently between the rocky summit area of these plateaus. Limestone plateaus with northward facing escarpments occur along the southern limit of the study area in Mali and Niger. Hamada surfaces with sinkholes characterize these plateaus. West of the Air and Adrar des Iforas are the Irahouriten and Timerin plateaus, respectively. Both of these areas are highly dissected with a series of eastward facing escarpments. The El Hank and Azlef plateaus occupy approximately 40,000 square miles in the west central part of the Northwest African Desert.

Bare rock and stony soils compose from 20 to 100 percent of the surface within the plateau regions of the study area. Relief in the summit areas generally ranges from several feet to 60 ft, but the depth of dissection along the major drainageways is usually from 100 to 800 ft.

Instituto de Estudios Africanos[13]

ient that forms the border of
ity of Buirat Well. Approxi-
29°17', W6°56'

Instituto de Estudios Africanos[13]

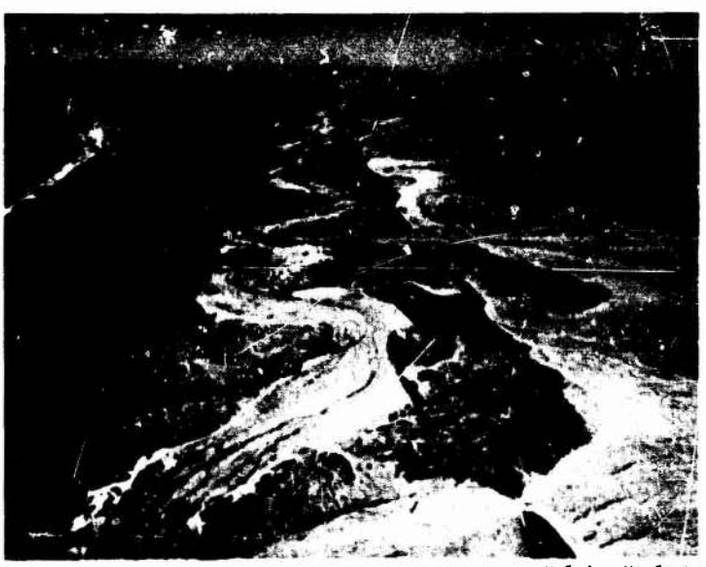
PL-3. A sand-filled reentrance into the plateau along the Spanish Sahara coast. The escarpments on the left part of the photo rise to the surface of the plateau. Approximate location N24°00', W15°37'

RIPTIONS AND PHOTOGRAPHS

PLAINS:

Plains are extensive tracts of flat to gently sloping land with hills, where present, occupying less than 25 percent of the surface. Desert, depression, alluvial, and coastal plains occupy approximately 38 percent of the Northwest African Desert. Desert plains occupy by far more area than the other types of plains in the study area. A slightly dissected desert plain extends along the southern limit of the Saharan Atlas in Northern Algeria. This plain is joined by a relatively narrow desert plain that separates the Grand Erg Oriental and the El Gautara Plateau. West of the Ahaggars and lying in the approximate center of the study area is the Taureg Tanzerouft. This desert plain is a lifeless, barren expanse of terrain occupying approximately 30,000 square miles. A similar, smaller plain occurs east of the Ahaggars and north of the sand dune region of the Tenere. Dikes and sand-silt basins interrupt the flat to slightly undulating surface of the Karet Plain in northern Mauritania. In southwestern Mauritania, desert plains occur between the stabilized dunes and the Atar Plateau. The plains of the El Djouft Basin, a hill land (sand dune) and desert plain complex in Mauritania and Mali, vary from undissected silt flats to surfaces crossed by widely spaced wadis. Lying between the Adrar des Iforas, the Southern Tassili, and the Plateau Irhaquriten is a desert plain slightly dissected by an old wadi system. South of the fixed dunes in Niger, the desert plain surface is spotted with shallow sinks.

Depression plains, where elevations below sea level occur, constitute the Tunisian-Algerian chott system which stretches for about 230 miles in the northeast part of the study area. This system of muddy saline depressions includes the Chotts Djerid and El Rharsa in Tunisia and the Chott Melrhir in Algeria. The Chott Djerid covers about 1900 square miles, and elevations as low as 52 ft below sea level occur. The Chott el Rharsa is separated from the Chott Djerid by a sill, and occupies an area of



U. S. Army Map Service

P-1. An oblique view of the floodplain of Wadi Dra lying between a curving continuous ridge on the left and a discontinuous sinuous ridge on the right. Alluvial apron band occurs at the base of the hills (upper right of the photo). Approximate location N28°20', W9°35'

P-2. Inselbergs rising
A thin layer of sand ver
cept in the lower left co
where the flattened cry
exposed. Approximate

400 square miles with a minimum elevation of 69 ft below sea level. The Chott Melrhir incloses an area of approximately 600 square miles wherein a minimum elevation of 100 ft below sea level is reached. The Sebkha Tindouft in Algeria and the sebkhas at the base of the Hamada el Haricha in Mali are the remaining mapped depression plains in the study area.

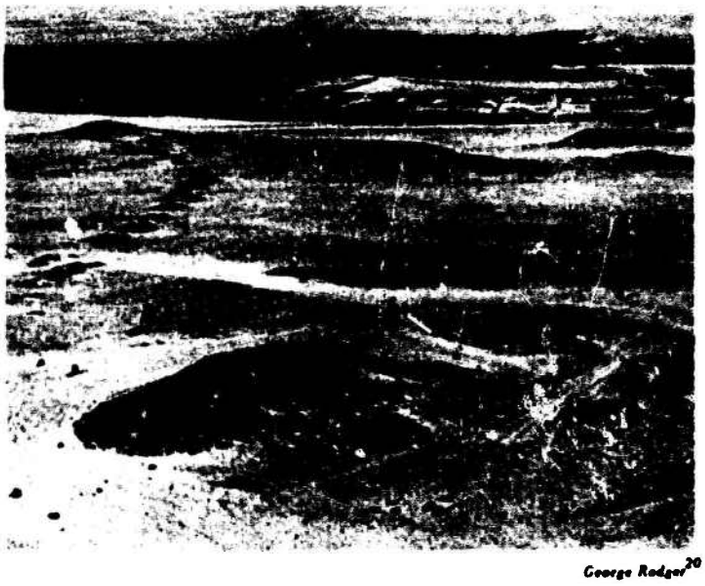
Coastal plains in the Northwest African Desert include a 15- to 60-mile-wide continuous strip in Tunisia adjacent to the Mediterranean Sea, and discontinuous strips in Mauritania, Spanish Sahara, and Morocco adjacent to the Atlantic Ocean.

The major alluvial plains in the Northwest African Desert are located along the Wadis Sous, Dra, and Saguio el-Hamra and the Niger River. The Sous Plain is triangular in shape and is bordered on the north by the High Atlas and the south by the Anti-Atlas Mountains. The Dra Plain is a narrow band along the Morocco-Algeria and Morocco-Spanish Sahara boundaries. The Saguio el-Hamra Plain, irregular in shape, extends approximately 250 miles across the northern part of Spanish Sahara. The Niger River makes an arc through the southwestern part of Niger. This plain enters the study area as a narrow floodplain which widens to form a low, marshy "inland delta" prior to continuing southward outside the desert limits.

Plains within the study area are composed of material ranging from clay to sand and gravel to bare rock and stony soils. Local relief seldom exceeds 50 ft.

Institut Géographique National, France[18]

sing above a desert plain.
d veneers this plain ex-
ft corner of the photo
crystalline basement is
nate location
1E1 E2000'



George Rodger[20]

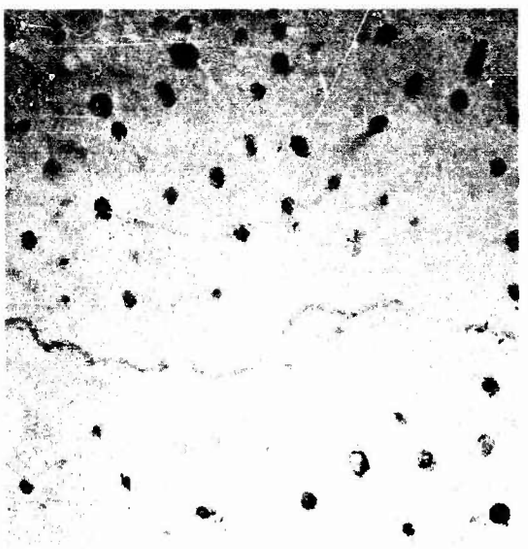
P-3. The desert plain surrounding the village of Reggane. Location N26°43', E0°10'

PL-1. A meandering valley carved in a sandstone plateau near Arak. Aeolian action has accentuated the irregular surface and the cuts along the edge of the plateau. In the background is a desert plain with scattered hills.
Approximate location N25°17', E5°21'

the Draa Plateau in the vicinity of Bui
mate location N29°17', W

Robert Perret[2]

PL-4. The relatively level rock fragment covered hamada surface of the Plateau Tademait. Exact location unknown



U. S. Army Map Service

PL-5. Aerial view of sinkholes developed in a limestone plateau in Algeria. Location N33°13', N01°38'

PL-8. Aerial view of mesas in Northwest Mauritania. Exact location unknown

PL-9. Aerial oblique showing stages o
region in Spanish Sahara. Various sta
the surface features exhibiting similar
erenced to the general level of plateau
Approximate location N27°45

† Raised numbers refer to similarly numbered entries in the photographic bibliography at the end of volume I of

the vicinity of Buirat Well. Approxi-
ocation N29°17', W6°56'

Spanish Sahara coast. The escarpments on the left part of the photo rise to the surface of the plateau. Approximate location N24°08', W15°37'

La Belle Image[9]

PL-6. Salt encrusted surface of the Sebkra d'Ouga. At N29°44', W2°07'

U. S. Army Map Service

PL-7. Aerial oblique of the Richat, a breached dome in the plateau region of Southwest Mauritania. At N21°15', W11°30'

U. S. Army Map Service

ue showing stages of erosion in a plateau
hara. Various stages are marked by
exhibiting similar elevations when ref-
ral level of plateau in the background.
ate location N27°45', W12°05'

Theodore Monod[17]

PL-10. The edge of the El Hank plateau north of Tagusalet in Mauritania. Approximate location N24°13', W6°58'

e end of volume I of this report.

continuous sinuous ridge on the right. Alluvial apron band occurs at the base of the hills (upper right of the photo). Approximate location N28°20', W9°35'

cept in the lower left corner of the pho where the flattened crystalline baseme exposed. Approximate location N23°15', E3°00'

Institut Géographique National, France[14]

P-4. Aerial view of consolidated dissected hills (in the lower right) bordered by an alluvial apron which grades into a relatively flat desert plain. Note the isolated barchan dunes (lower left) and the longitudinal dunes (upper right) on the plain. Approximate location N23°20', W12°39'

P-5. The multichannel bed of the Wadi Sa Reggane. Approximate location N26°49

Compagnie Générale Transsaharienne[9]

P-7. Automobile tracks penetrating the sandy surfaces of the Tanzeruft, a vast, featureless plain which lies in the heart of the Northwest African Desert. Approximate location N22°18', E1°05'

U. S. Army M

P-8. Aerial view of a drainage networ desert plain. Approximate location N29°35', E07°45'

left corner of the photo
ed crystalline basement is
imate location
°15', E3°00'

R. H. Forbes[10]

el bed of the Wadi Saoura near
mate location N26°49', E0°07'

U. S. Army Map Service

P-6. Aerial view of a desert plain -- sand covered in the foreground with rock outcrops occurring near the plateau escarpment in the background. The road-like pattern in the center foreground is a low dike. Location N25°35', E12°20'

U. S. Army Map Service

of a drainage network on a
proximate location
°35', E07°45'

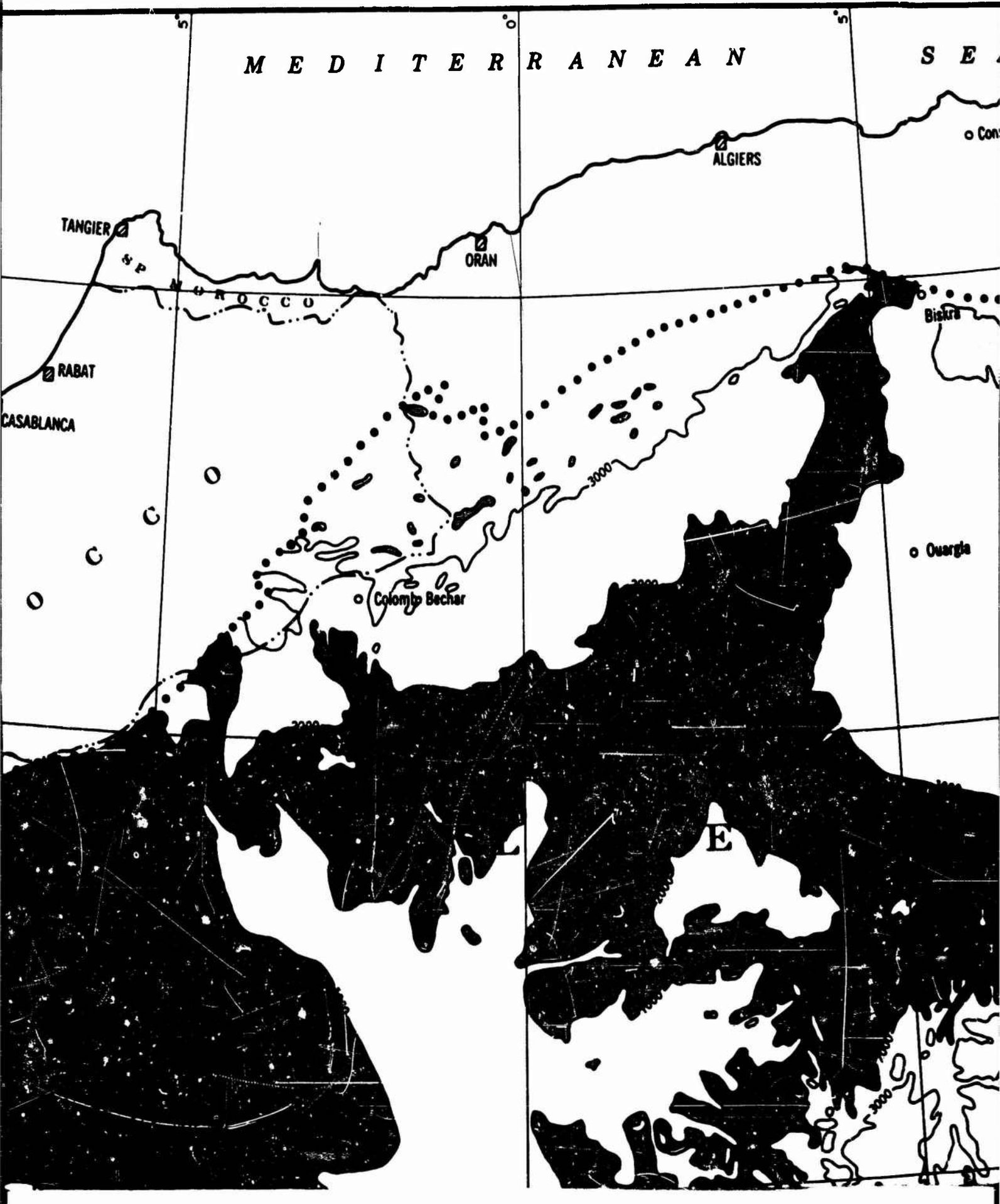
ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

PHYSIOGRAPHY

DESCRIPTIONS AND PHOTOGRAPHS


20°
15°
10°
35°
ATLANTIC
OCEAN
MARRAKECH
30°
25°
VILLA CISNEROS

2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SEA
ALGIERS
TANGIER
ORAN
SP. MOROCCO
Biskra
RABAT
CASABLANCA
3000
Ouargla
Colomb Bechar
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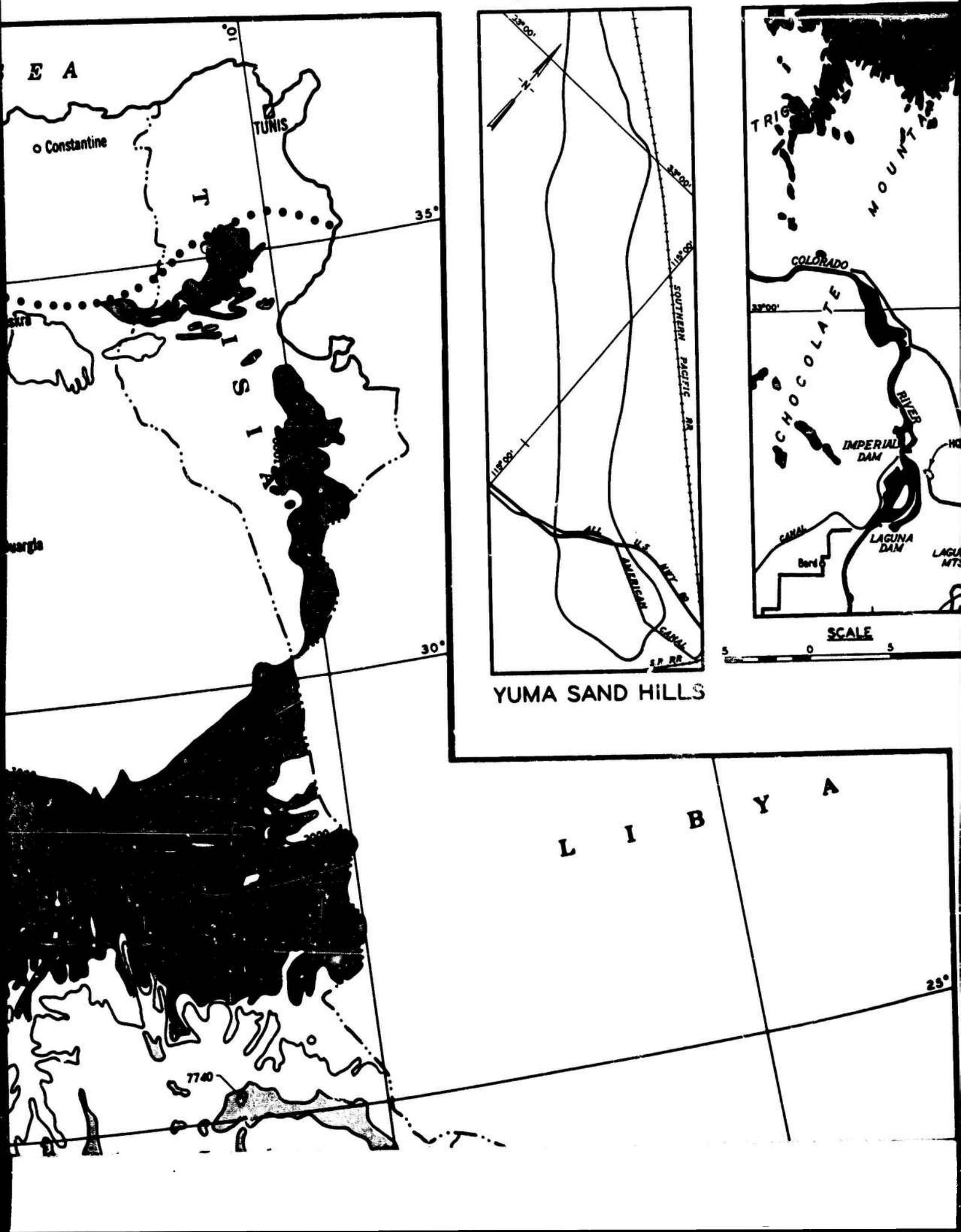
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L I B Y A
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115°00'
SOUTHERN PACIFIC RR
U.S. NAT'L RR
AMERICAN CANAL
S.P. RR
YUMA SAND HILLS
TRIG
MOUNTAINS
COLORADO
CHOCOLATE
RIVER
IMPERIAL DAM
LAGUNA DAM
CANAL
SCALE
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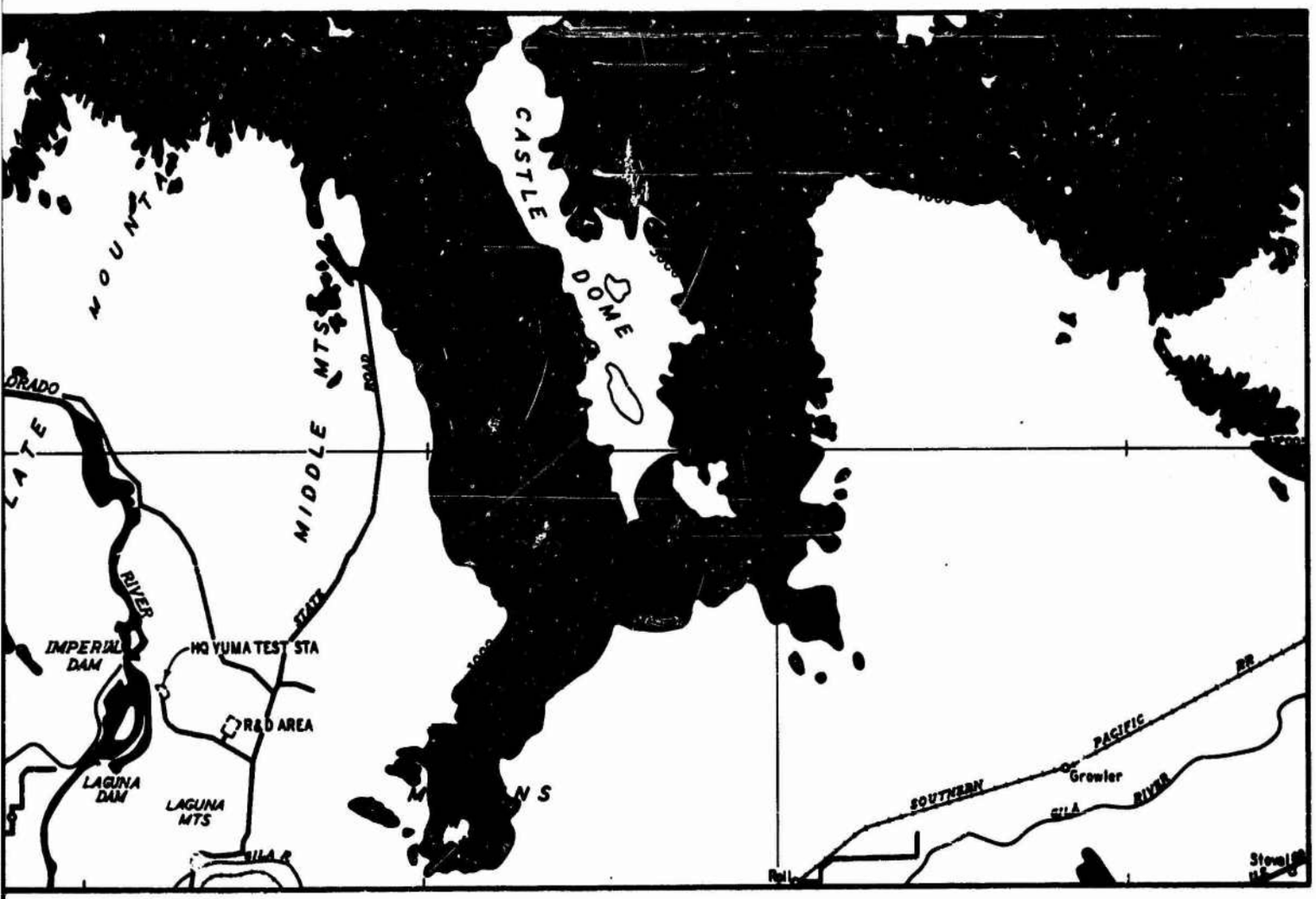
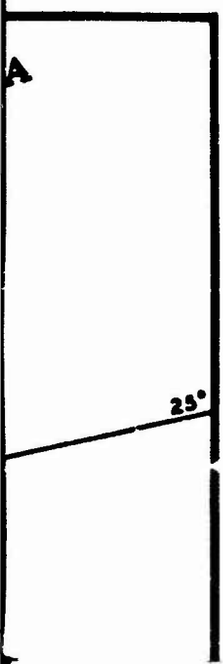
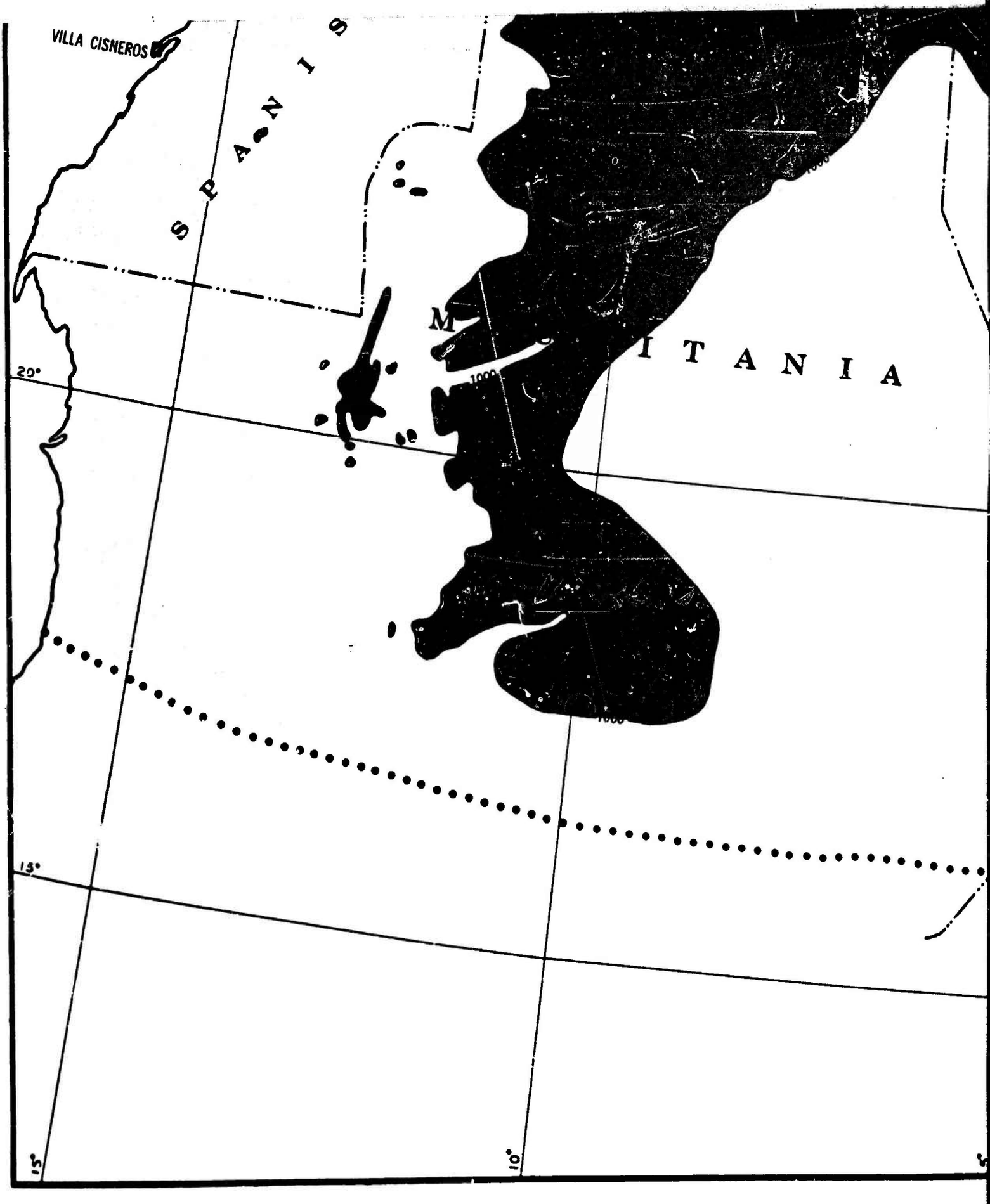


YUMA TEST STATION

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ITANIA
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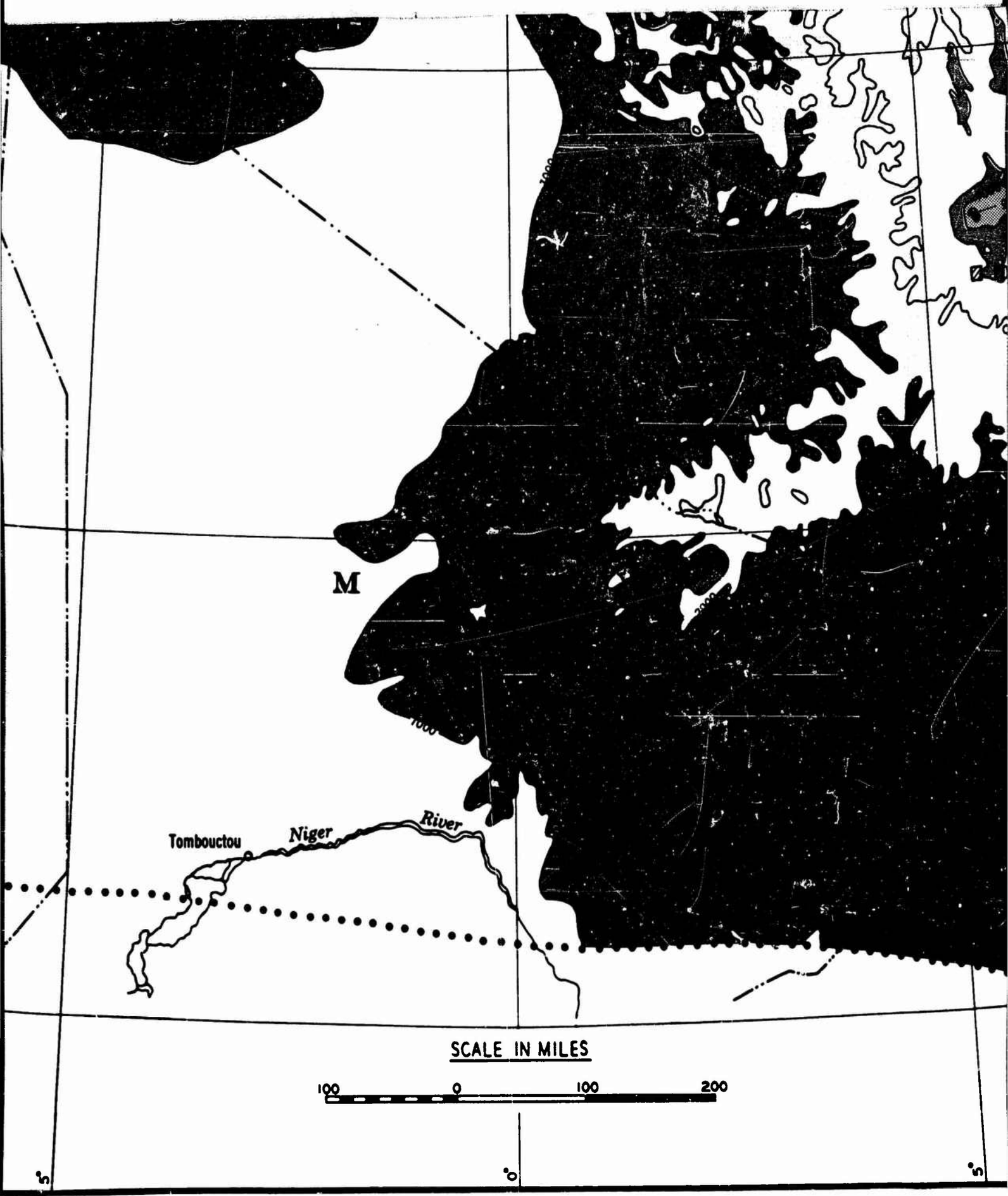
M
Tombouctou
Niger
River
SCALE IN MILES
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5°
0°
5°


3000
3000
2000
PORT LAPERRINE
20°
15°
Lake
Chad
NIGERIA
5°
10°

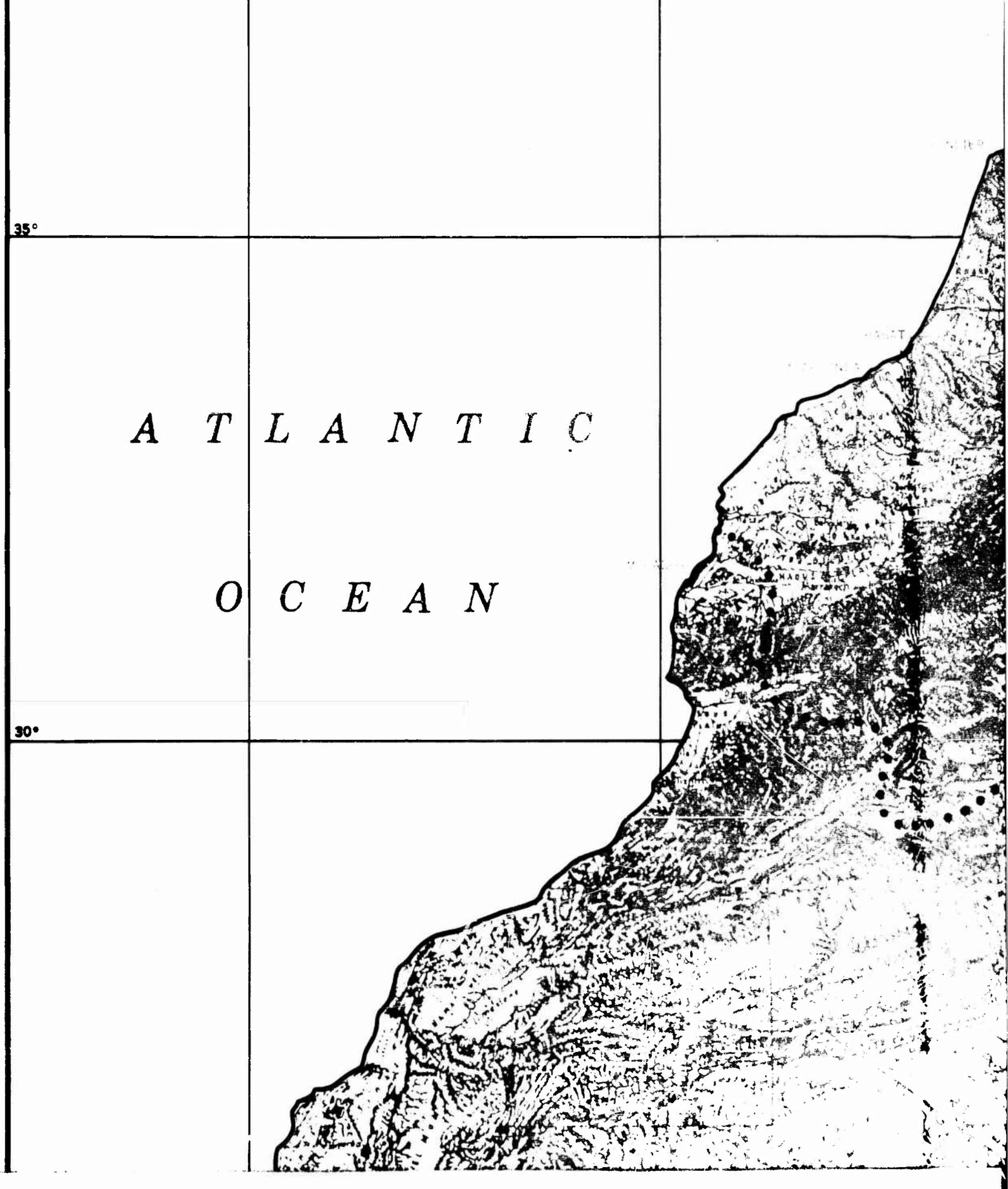
HYPSOMETRY

1		Below sea level
2		0 to 1,000 feet
3		1,000 to 2,000 feet
4		2,000 to 3,000 feet
5		3,000 to 5,000 feet
6		5,000 to 7,000 feet
7		7,000 to 9,000 feet
8		9,000 to 12,000 feet
	•—7740	Spot elevation in feet

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

HYPSOMETRY

PLATE 16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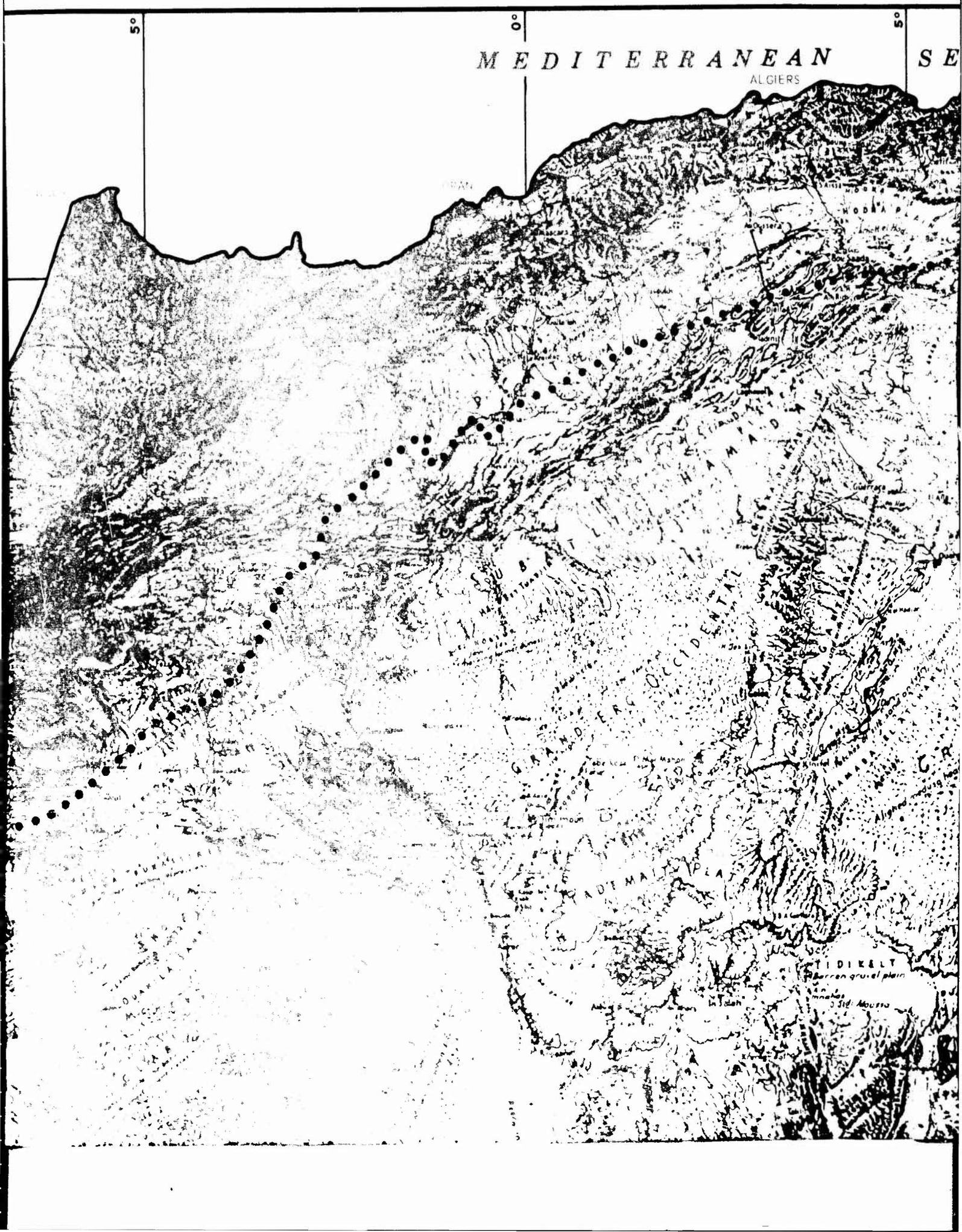
10°
35°
A T L A N T I C
O C E A N
30°


5°
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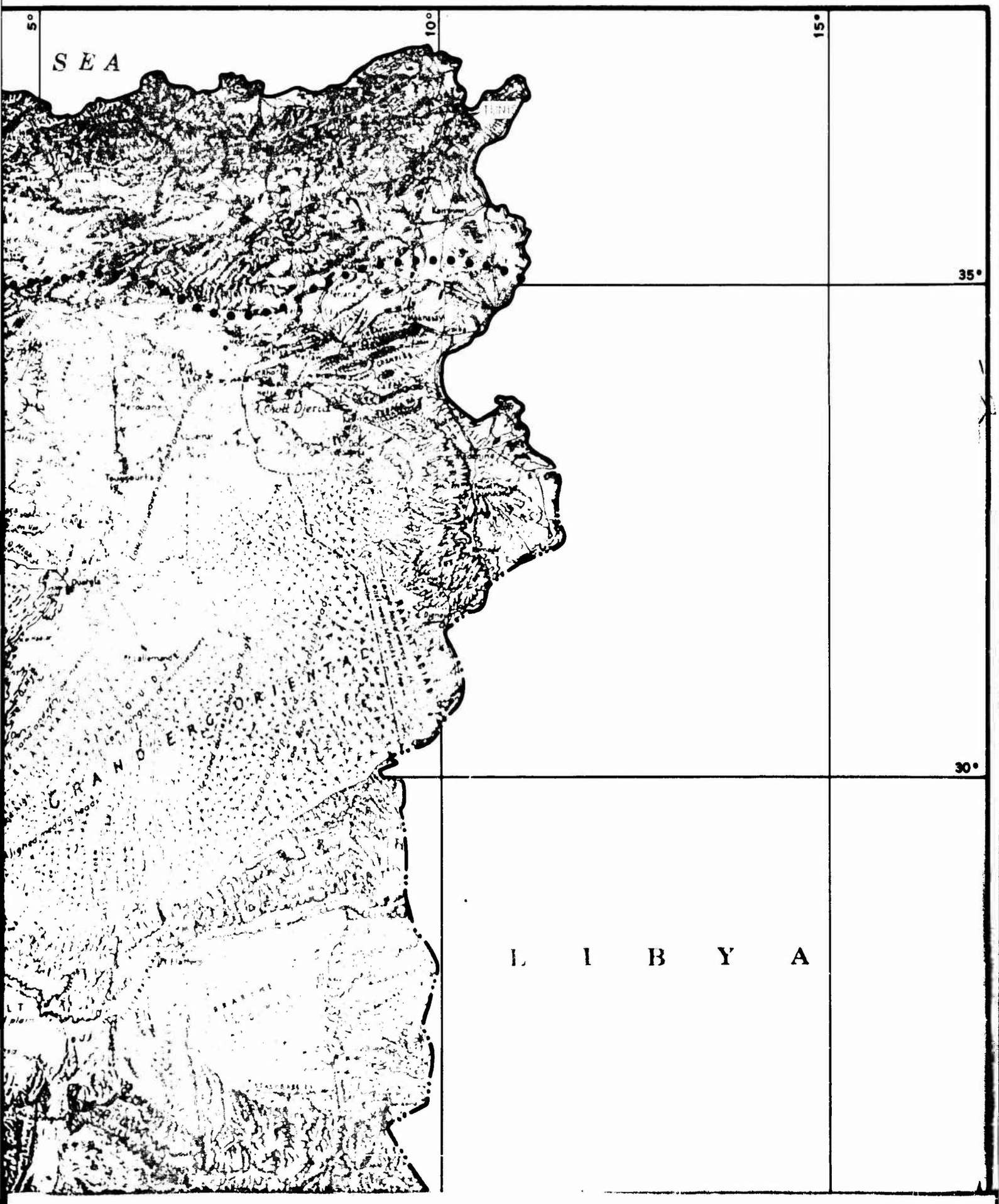
MEDITERRANEAN
SE
ALGIERS
HAMADA
GRAND ERG OCCIDENTAL
TIDIKELT
Barren gravel plain


5°
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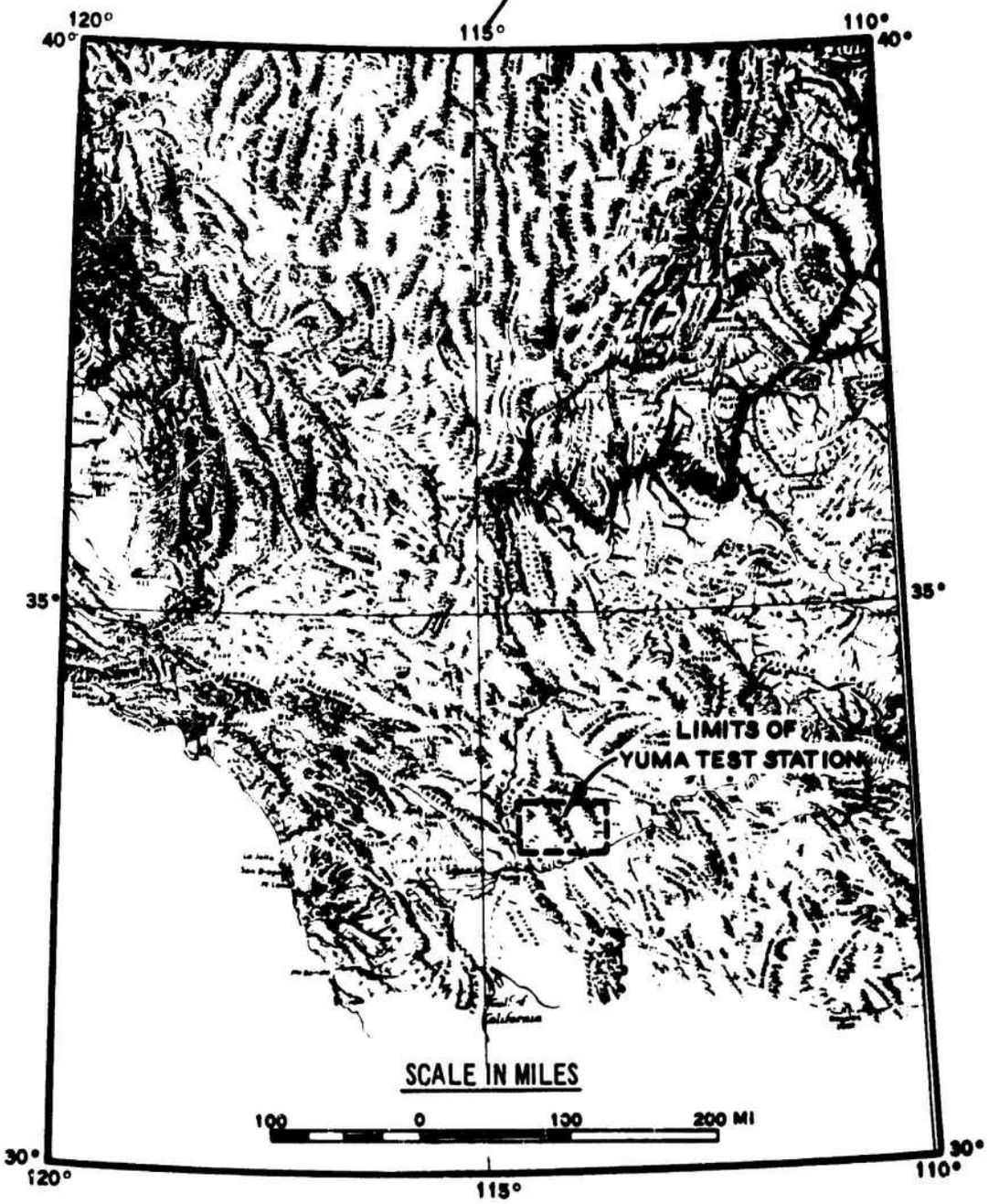
Chott Djerid
GRAND ERG ORIENTAL
LIBYA

4



SOUTHWESTERN UNITED STATES

Reproduced from Map of the Landforms of the United States by Permission of Erwin Raisz and Ginn & Co.

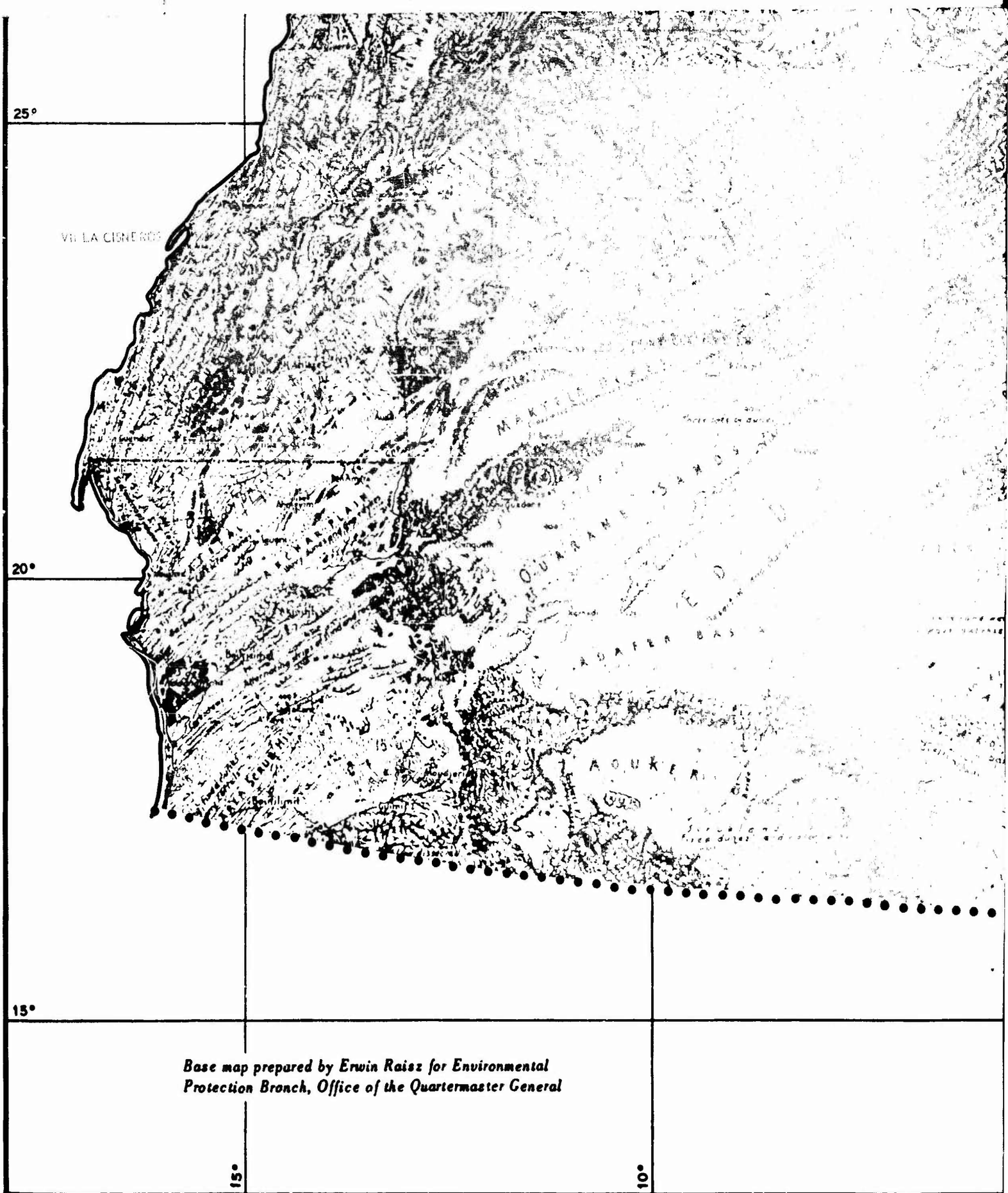
GLOSSARY

Agobo, Agabo	Pass, accent	Jarf	Bank, cliff
Aoged	Low knoll	Jebel	See Gebel
Argub	Ridge spur	Kher, pl Khoiren	Water course
Bab pl Beiben	Pass	Maoien	Well
Bahr pl Buhur	Sea, river	Mashra	Ford, watering place
Barchan	Crescent dune	Minger	Cliff, bluff
Barqan, Berga	Sandy area	Migreh, Miqreh	Water shed
Dahr, Dahar	Tableland	Mitla	Pass, accent
Daib	Rest track	Nagb, Nagb	Pass
Debbe	Sandy plain	Neggara	Cliff, accent
Deir	Depression	Nueb	Knoll, bluff
Der, Dueir, Duer	Group of hills	Qalti pl Qulut	Rock pool
Erg, Ergh	Dunes, dune field	Qaz pl Qoizan	Dune
Fesh-fesh	Barchans, chalk, clay	Rmal ni Rimal	Sand

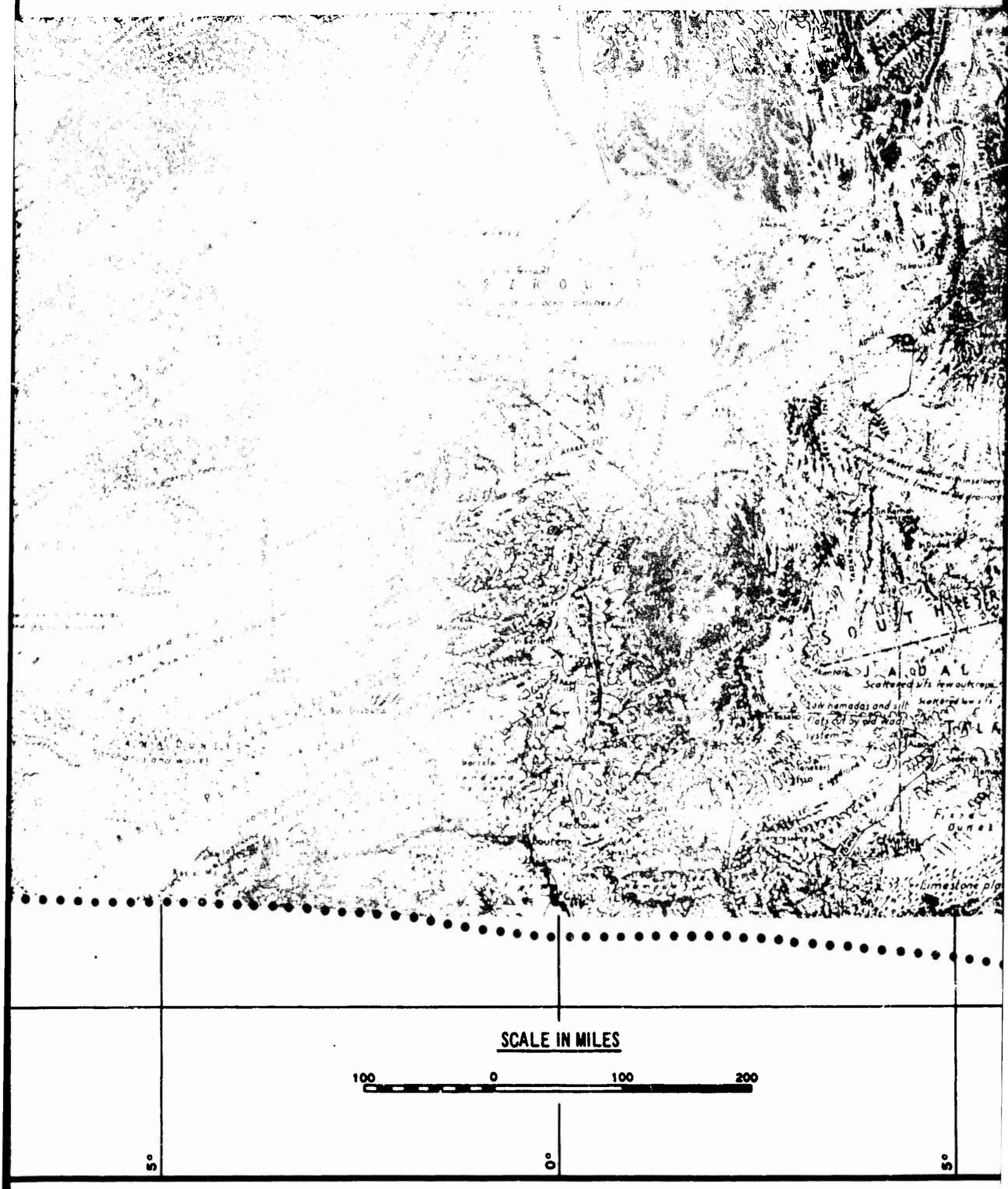
ABBREVIATIONS

A	Ain	Water hole
B	Bir	Well
D	Dahr	Mesa, tableland
G	Gara	Low hill
HA	Hamada	Rock flat
J	Jebel	Mountain
K	Kher	Dry river
Q	Qasr	Fort
S	Sebcha	Salt flat
W	Wadi	Water course

IN FRENCH



Base map prepared by Erwin Raisz for Environmental Protection Branch, Office of the Quartermaster General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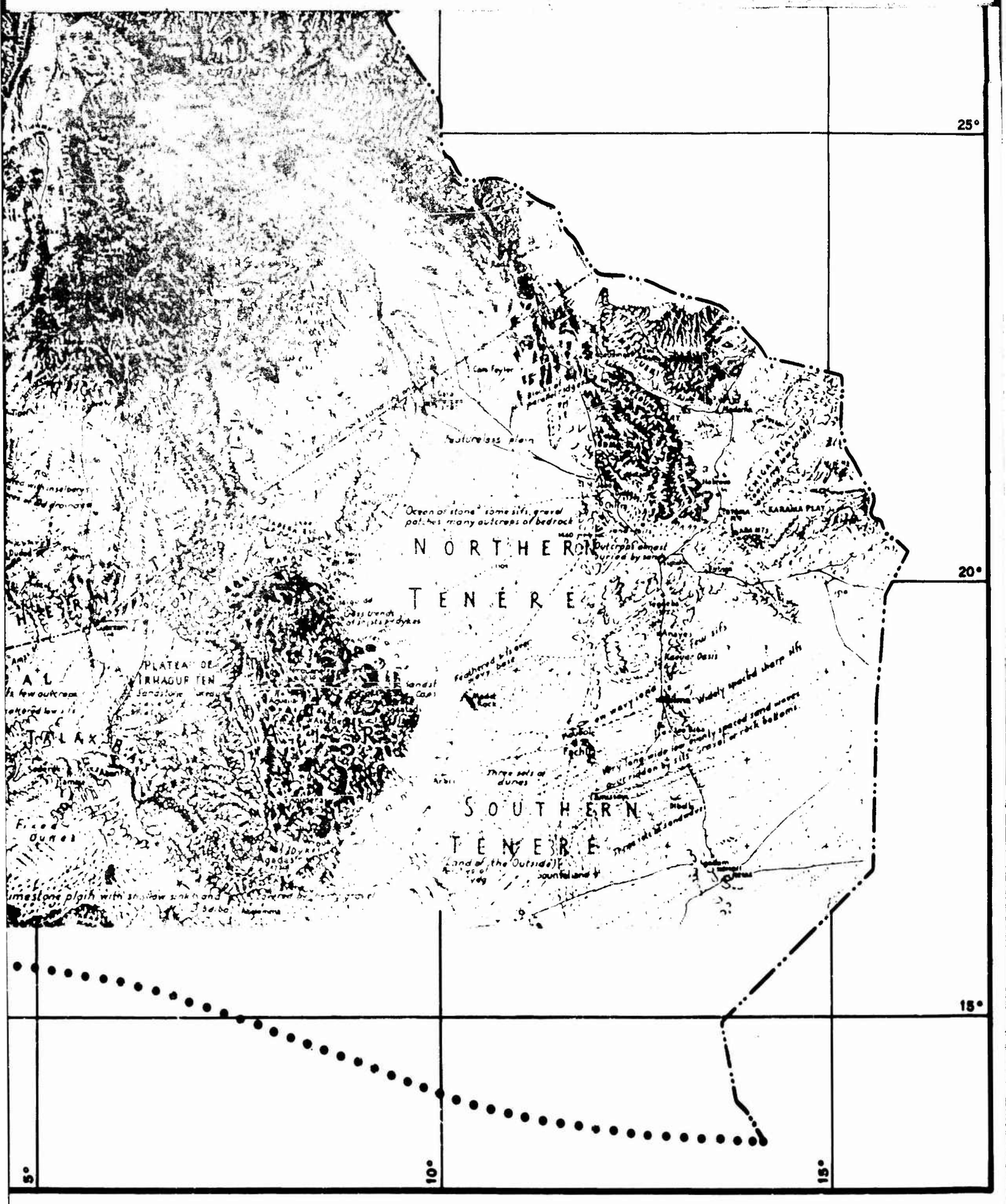

25°
20°
15°
5°
10°
15°
NORTHERN
TENERE
SOUTHERN
TENERE
PLATEAU DE
TIHAGUR TEN
TALAK
Ocean of stone" : stone silt, gravel
pebbles, many outcrops of bedrock
Land of the Outsiders
Limestone plain with shallow sinkholes
Agadez

Daib	Road track	Nagb, Naqb	Pass
Debbe	Sandy plain	Neggaze	Cliff, ascent
Deir	Depression	Nusb	Knoll, bluff
Dor, Dueir, Duer	Group of hills	Qelti pl Qulut	Rock pool
Erg, Ergh	Dunes, dune field	Qoz pl Qeizan	Dune
Fash-fesh	Powdery chalk, clay	Raml pl Rimal	Sand
Gebel pl Gubal	Hill, mountain	Raqaba, Regbel	Water course
Ghard	Dunes	Sabakha, Sebkra	Salt marsh, bog
Gheib	Rocky hill	Sauwane	Flinty plain
Ghor	Deep valley	Seil	Flood bed
Gilf	Cliff, escarpment	Shilib	Branch wadi
Hagiag	Escarpment	Serir	Gravel desert
Halgh, Halaigh	Gorge, valley	Shorms	Saddle
Hammade	Stony plain	Themile	Water hole
Hasi	Water hole	Wadi, Ovad	Water course
Have	Cave	Solat	Stone, rocky ridge

Sebcha		Salt flat
W	Wadi	Water course

IN FRENCH

D^e	Daïa	Basin sink
Dj	Djebel	Mountain
G	Gour	Valley
H	Hassi	Well
Og	Ogiet	Many wells
O	Oued	Water course

The designations Ain, Bir, Hassi, Ogiet for water holes are sometimes omitted.

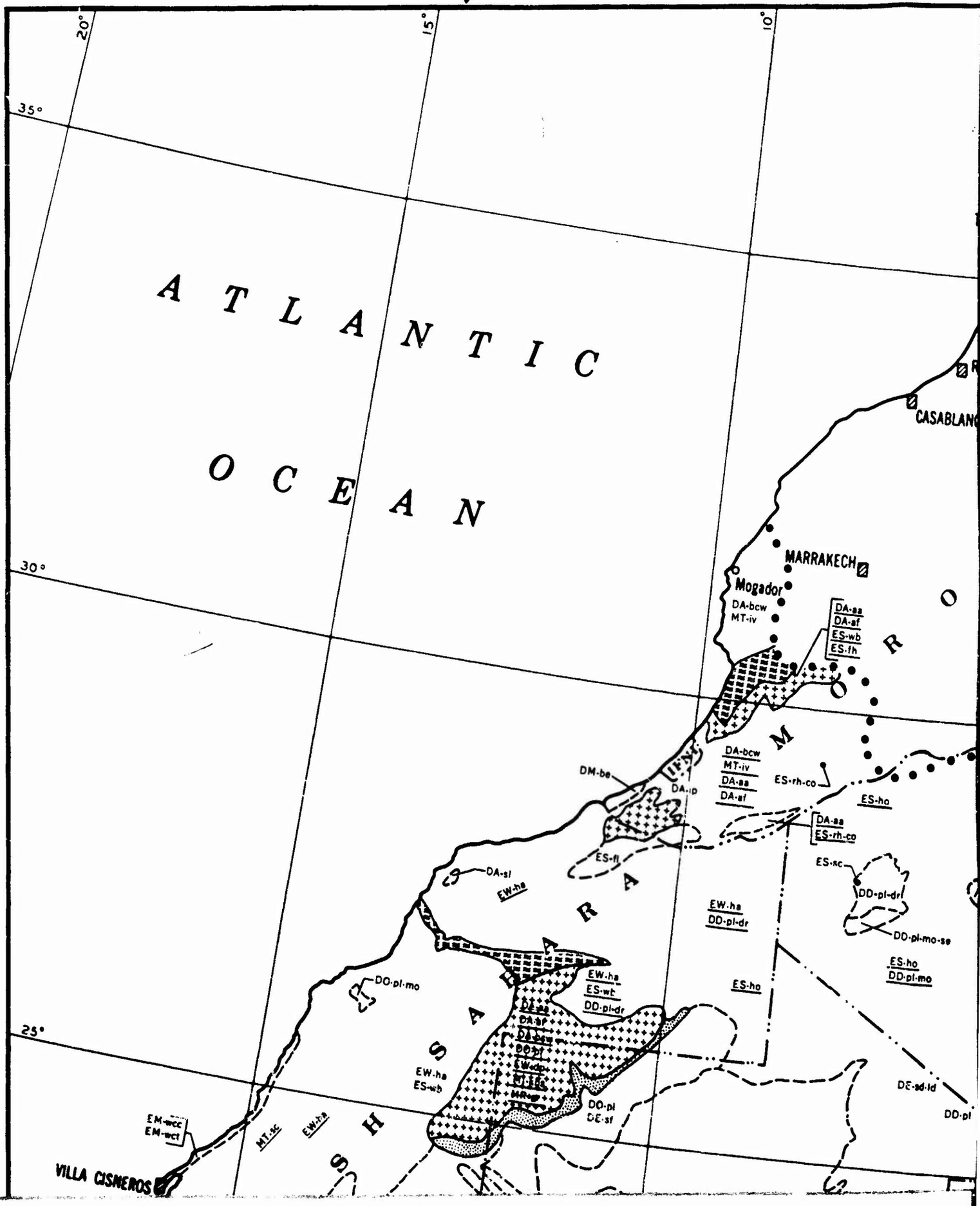
SYMBOLS

- Motor road
- Trail
- Railway
- Canal
- Settlement
- Water hole
- Oasis (not shown in the Atlas lands)
- Jebel (mountain)
- Dendritic sandstreams
- Dissected plateau
- Wind-etched limestone
- Knobby sandstone
- Lava
- Crystalline lowland
- Silt and sand flats
- Sifa (sword) dunes
- Barbed sifs
- Hasped dunes
- Barchans
- Gravel (serir, reg.)
- Sinkholes
- Salt lakes or flats
- Knob rows (mostly silurian sandstone)
- Closely set folds (mostly carboniferous sediments)
- Hamada with incised meanders

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT
RAISZ'S LANDFORM MAP

PLATE 17

4 8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15°
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OCEAN
CASABLANCA
MARRAKECH
Mogador
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DA-aa
DA-af
ES-wb
ES-fh
MOROCCO
DM-be
DA-ip
DA-bcw
MT-iv
DA-aa
DA-af
ES-rh-co
ES-ho
DA-aa
ES-rh-co
ES-fl
ES-sc
DA-sl
EW-ha
DD-pl-dr
EW-ha
DD-pl-dr
DD-pl-mo-se
ES-ho
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EW-ha
ES-wb
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ES-ho
SAHARA
EW-ha
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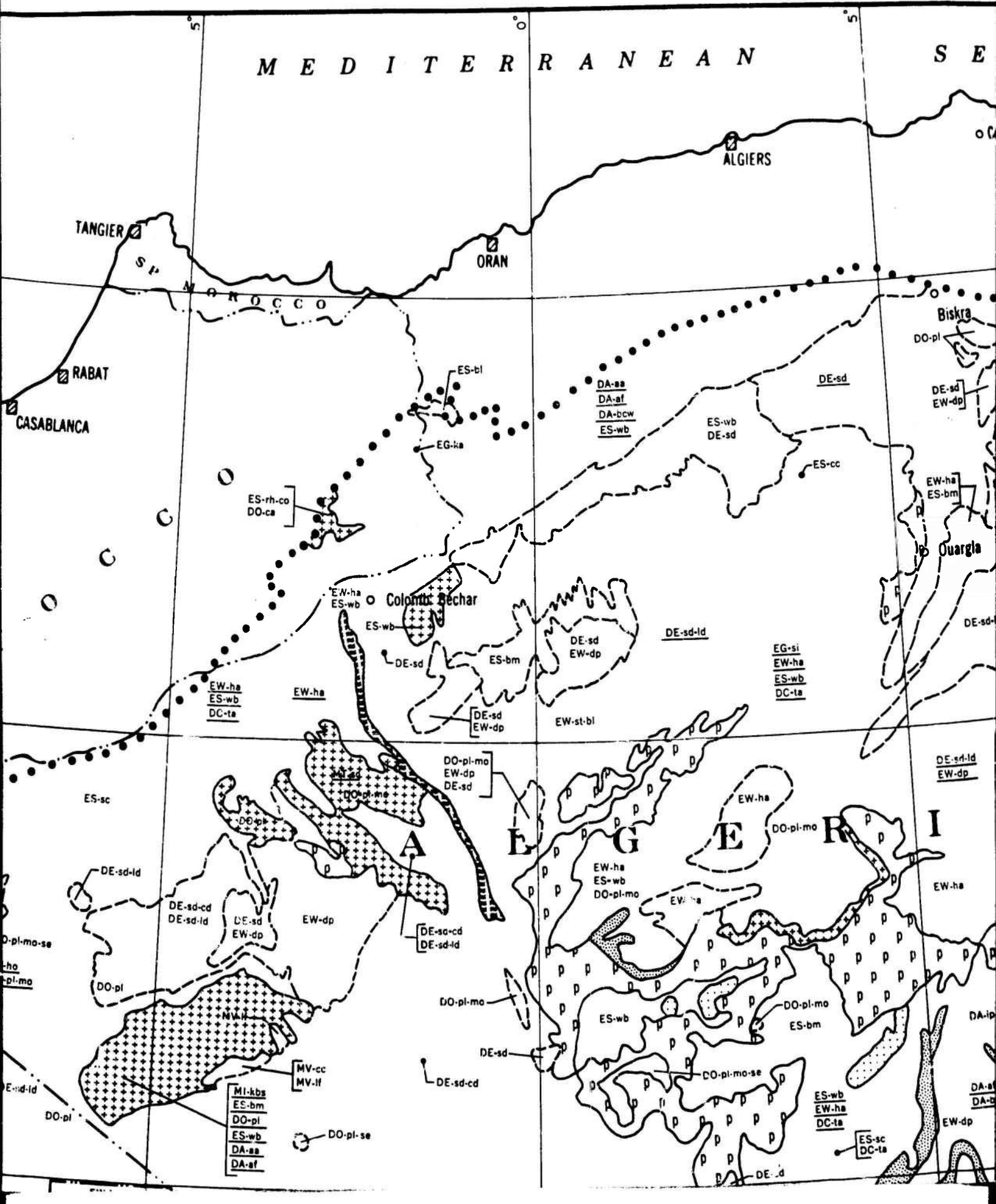
EW-ha
VILLA CISNEROS

2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ALGIERS
TANGIER
ORAN
RABAT
CASABLANCA
Biskra
Ouargla
Colomb Bechar
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ES-rh-co
DO-ca
DA-aa
DA-af
DA-bcw
ES-wb
DE-sd
ES-cc
EW-ha
ES-bm
EW-ha
ES-wb
DC-ta
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ES-bm
DE-sd
EW-dp
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EG-si
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DC-ta
EW-st-bl
DO-pl-mo
EW-dp
DE-sd
ES-sc
DO-pl
DE-sd-ld
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DE-sd-ld
DE-sd
EW-dp
EW-dp
DE-sd-cd
DE-sd-ld
DO-pl
MV-cc
MV-lf
MI-kbs
ES-bm
DO-pl
ES-wb
DA-aa
DA-af
DO-pl-se
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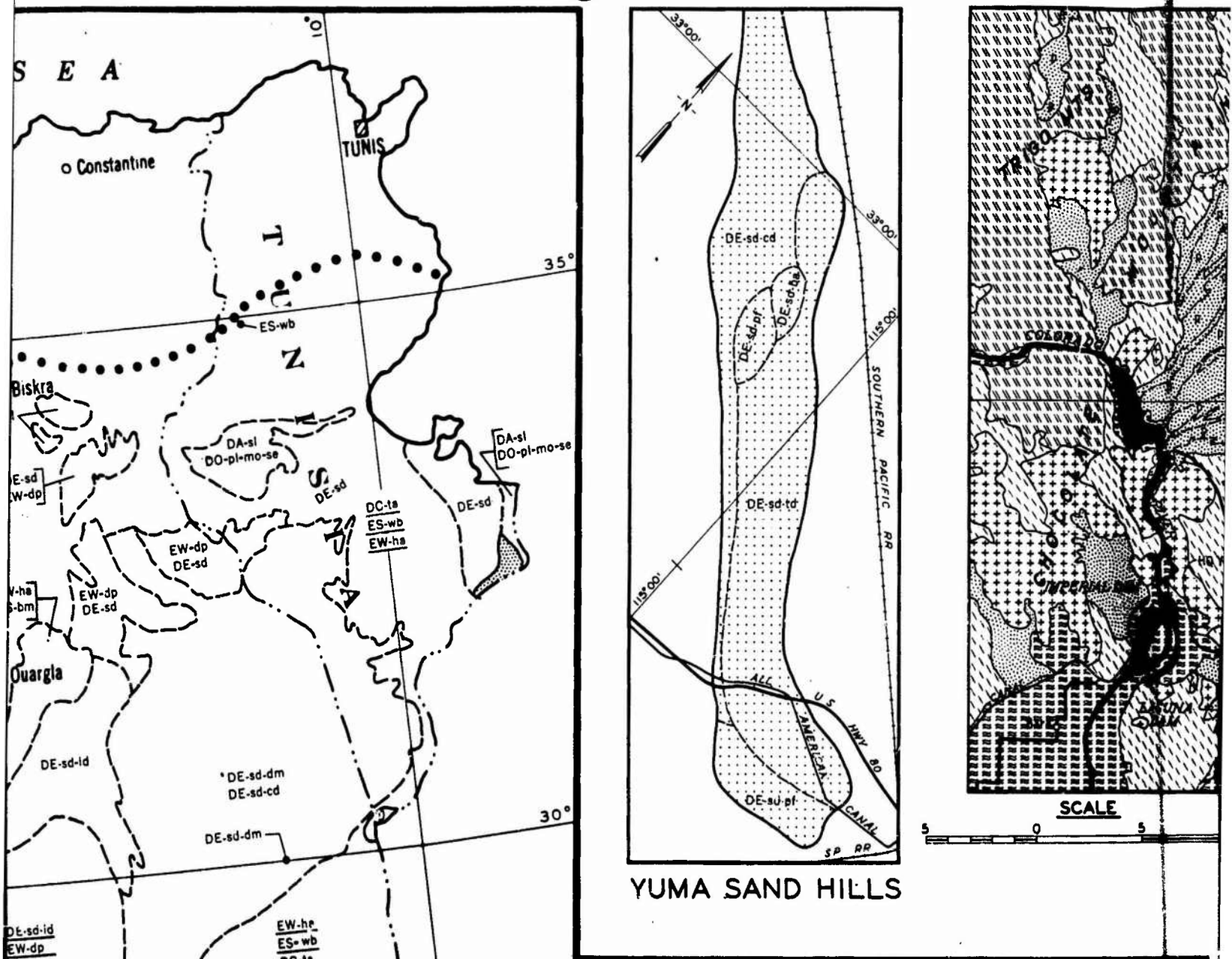
EW-dp

3


S E A
TUNIS
Constantine
35°
ES-wb
Biskra
DA-sl
DO-pl-mo-se
DE-sd
DC-ta
ES-wb
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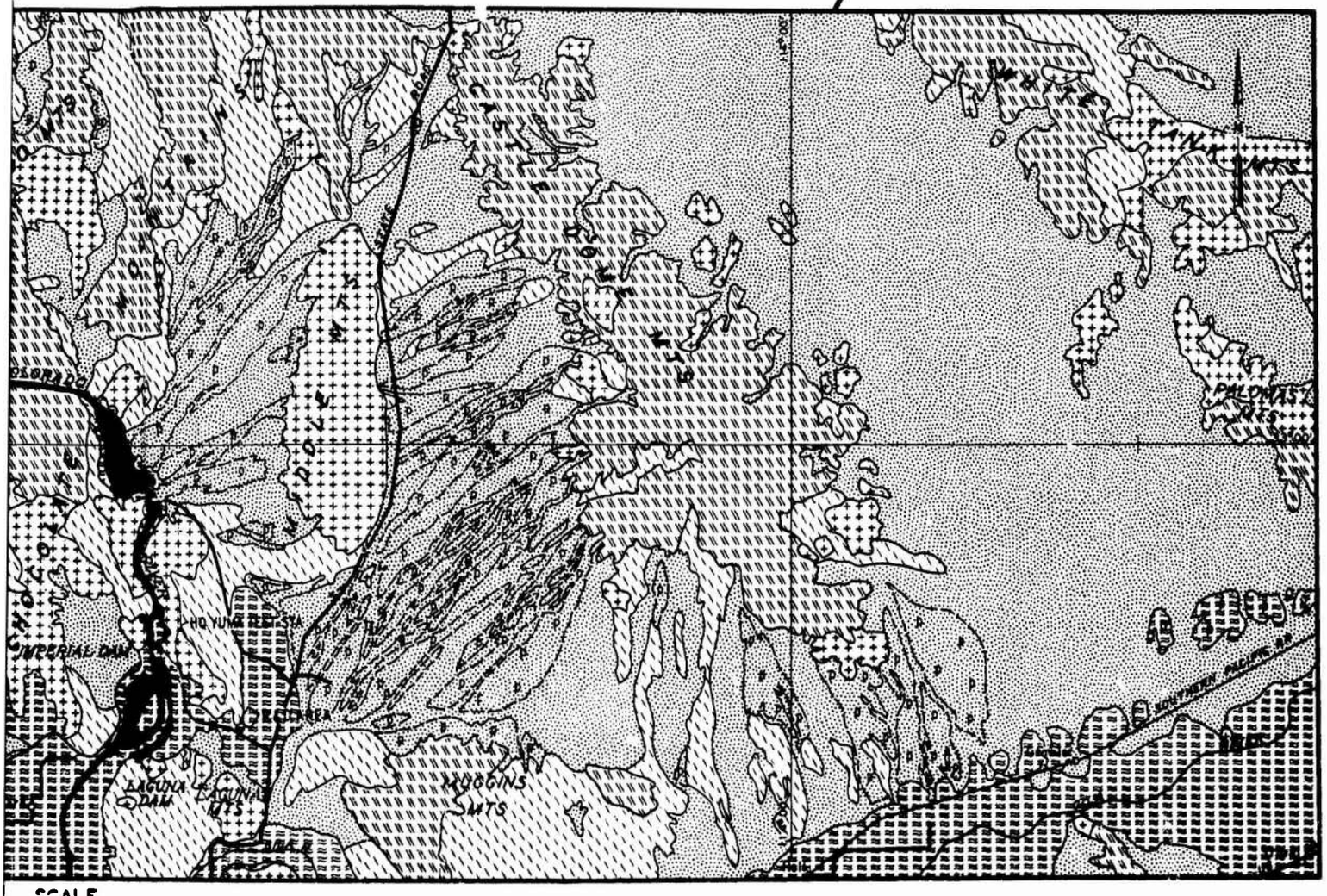
EW-dp
DE-sd
Ouargla
DE-sd-ld
DE-sd-dm
DE-sd-cd
30°
EW-he
ES-wb
DC-ta
EW-dp
EW-ha
FORT FLATTERS
DE-sd-cd
DE-sd-dm
ES-wb
DE-sd
EW-ha
ES-wb
DE-scw
DA-af
DA-bcw
EW-dp
MV-cc
MV-lf
MV-nps
MV-lf
ES-wb
DC-ta
DE-sd
L I B Y A
25°
33°00'
N
DE-sd-cd
DE-sd-ta
DE-sd-pf
DE-sd-td
115°00'
SOUTHERN PACIFIC RR
ALL AMERICAN CANAL
U.S. HWY 80
DE-su-pf
SP RR
YUMA SAND HILLS
COLORADO
IMPERIAL
SCALE
5 0 5

4



SCALE
0 5 10 MI.

YUMA TEST STATION

A

25°

SELECTED LANDFORMS AND SURFACE CONDITIONS

I. DEPOSITIONAL

ALLUVIAL

- Alluvial fans ..... DA-af
- Alluvial aprons ..... DA-aa
- Abandoned courses ..... DA-ac
- Bars and swales ..... DA-bs
- Boulder-choked wadis ..... DA-bcw
- Deltas ..... DA-de
- Floodplains ..... DA-fp
- Intermittent freshwater lakes ..... DA-ifl
- Intermontane plains ..... DA-ip
- Levee-flank depressions ..... DA-lfd
- Marsh ..... DA-ma
- Natural levees ..... DA-nl
- Oxbow lakes ..... DA-obl
- Salt lakes ..... DA-sl

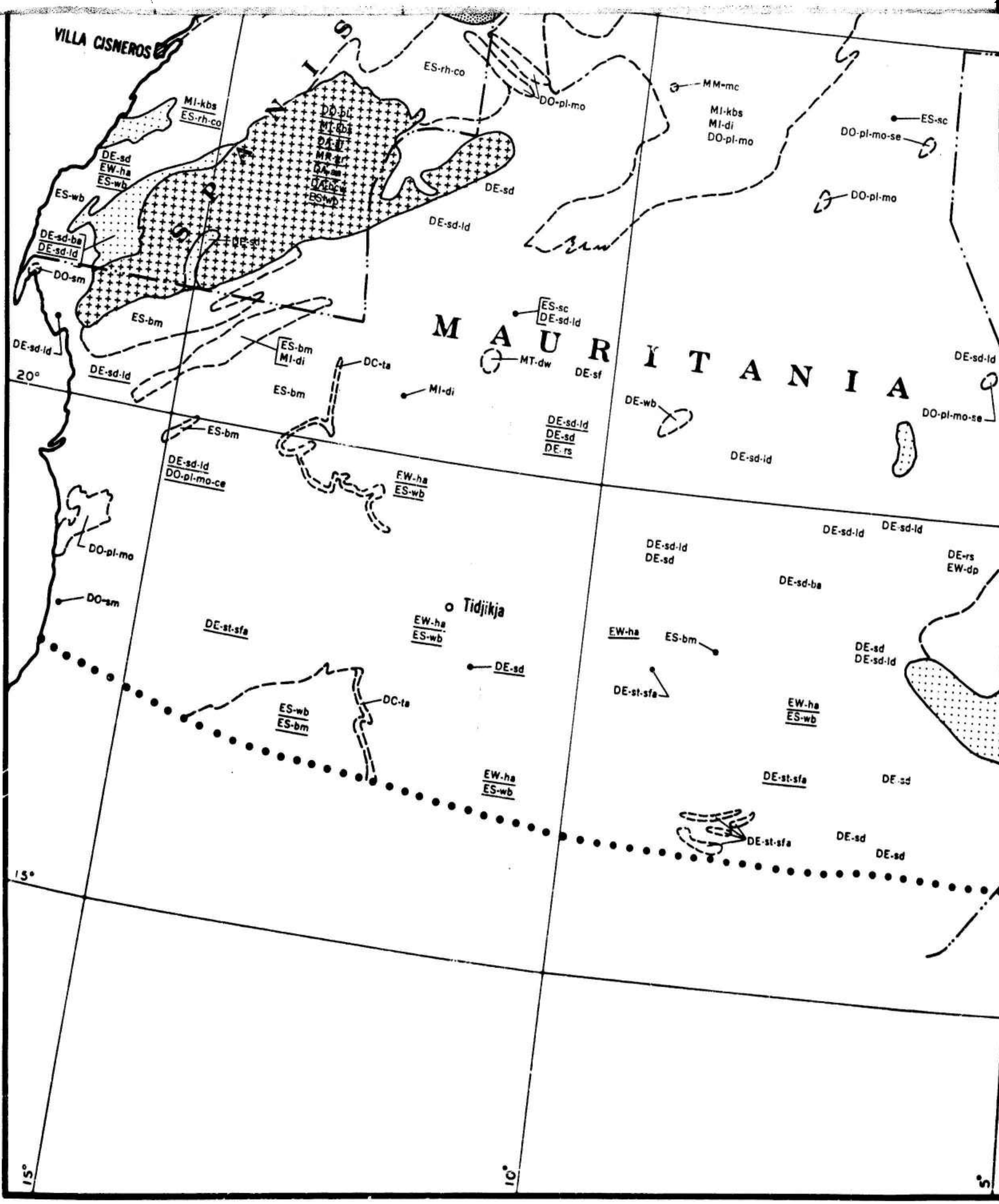
COLLUVIAL

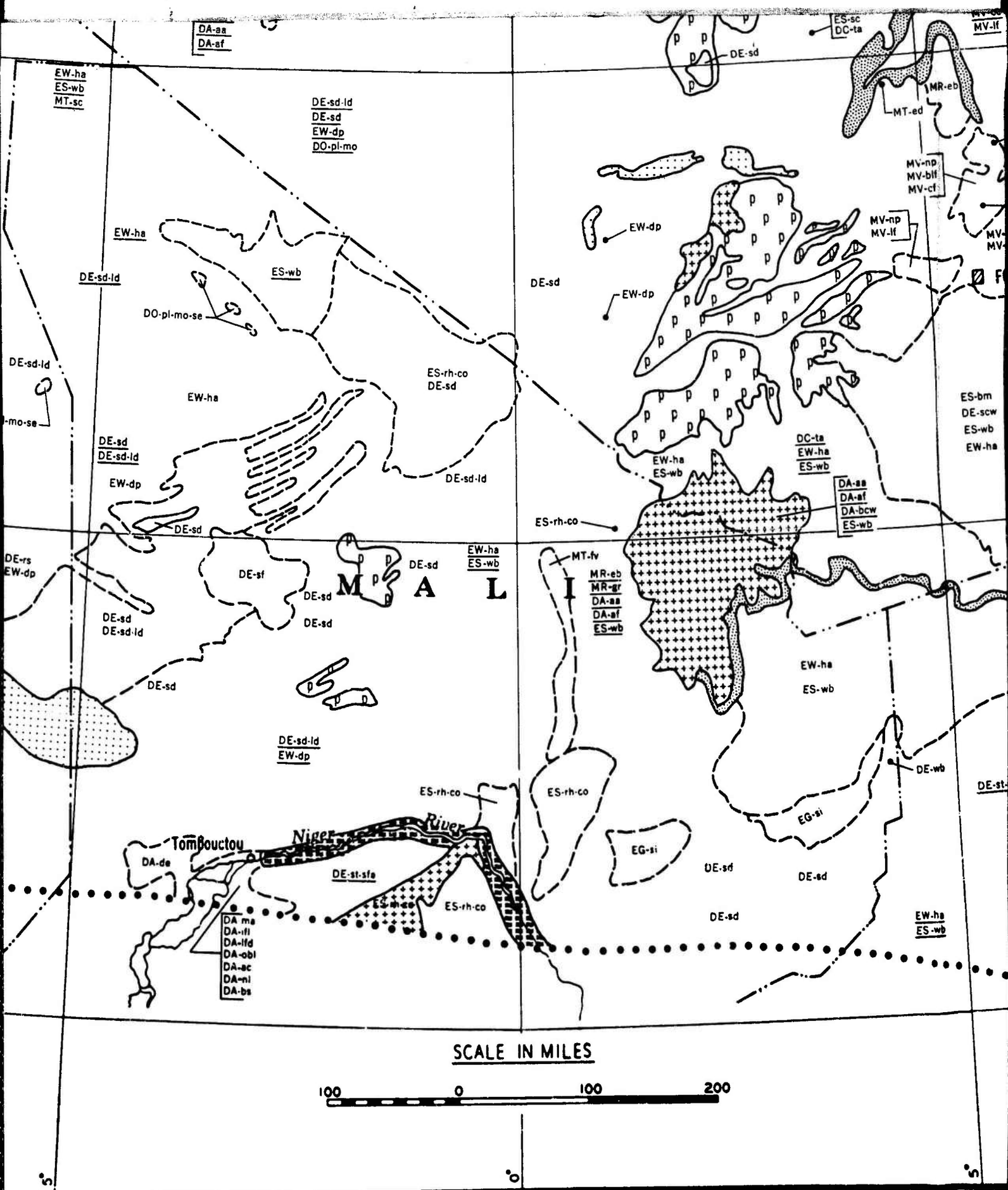
II. EROSIONAL (Continued)

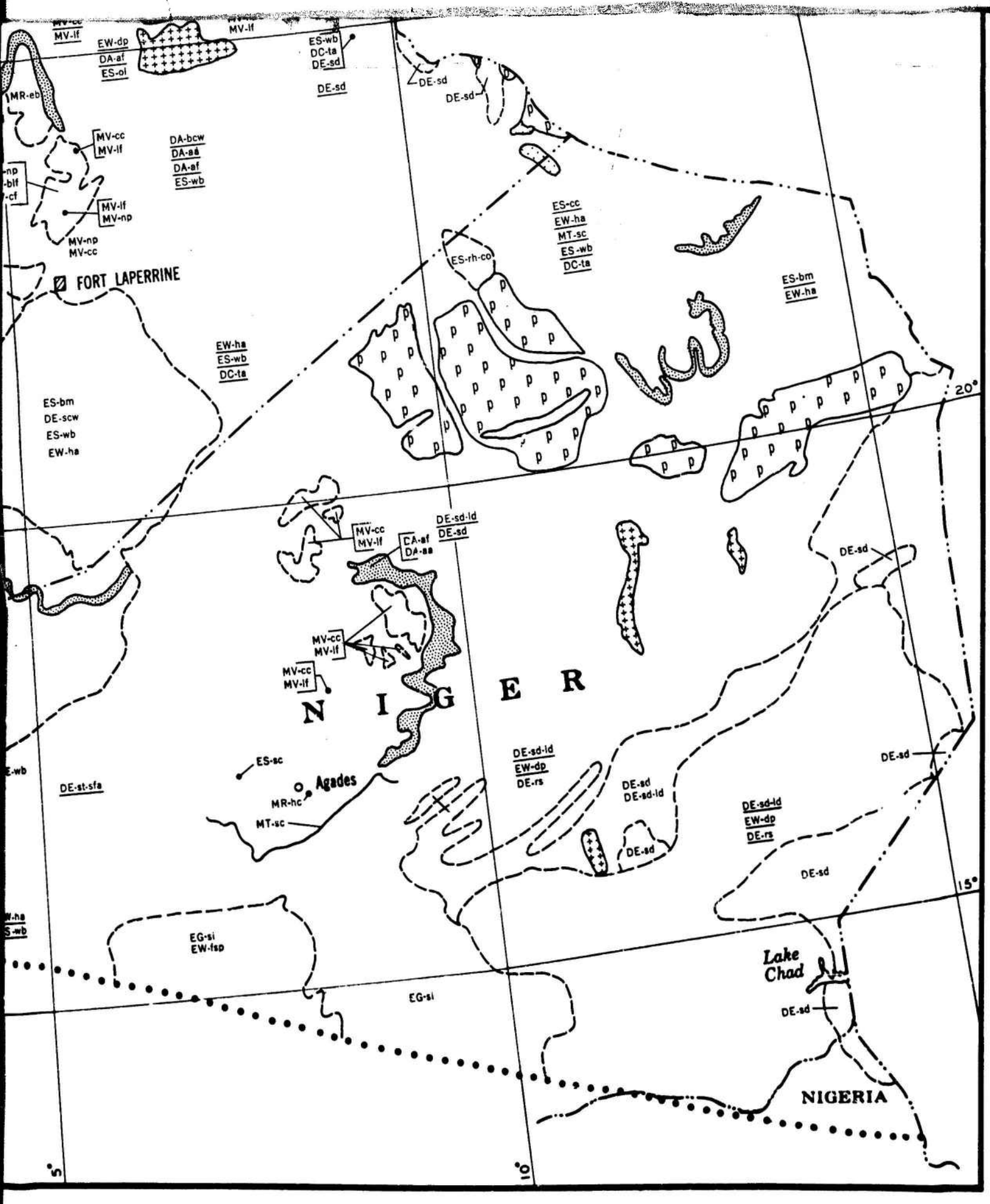
SURFACE WATER

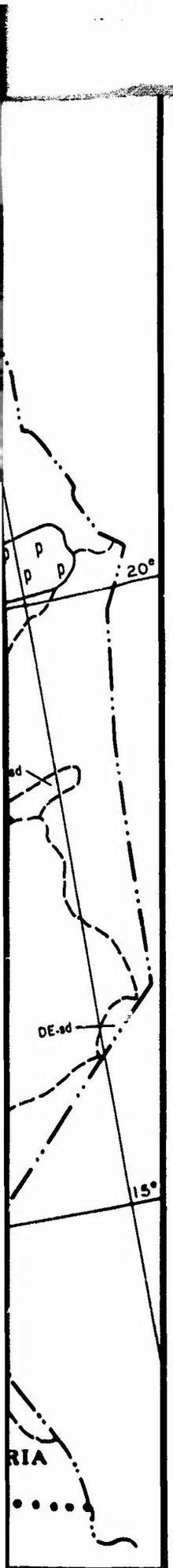
- Badlands ..... ES-bl
- Buttes and mesas ..... ES-bm
- Canyon country ..... ES-cc
- Flatirons ..... ES-fl
- Foothills ..... ES-fh
- Hogbacks ..... ES-ho
- Outliers ..... ES-ol
- Random hills (undiff.) ..... ES-rh
- Consolidated ..... ES-rh-co
- Unconsolidated ..... ES-rh-un
- Scarps ..... ES-sc
- Steep wadi banks ..... ES-wb

WIND


VILLA CISNEROS
SPANISH
MAURITANIA
Tidjikja
MI-kbs
ES-rh-co
DE-sd
EW-ha
ES-wb
ES-wb
DE-sd-ba
DE-sd-ld
DO-sm
DE-sd
ES-bm
DE-sd-ld
DE-sd-ld
20°
ES-bm
MI-di
ES-bm
ES-bm
DE-sd-ld
DO-pl-mo-ce
DO-pl-mo
DO-sm
DE-st-sfa
ES-wb
ES-bm
DC-ta
DC-ta
EW-ha
ES-wb
EW-ha
ES-wb
DE-sd
EW-ha
ES-wb
MI-di
ES-rh-co
DO-pl-mo
DE-sd
DE-sd-ld
ES-sc
DE-sd-ld
MT-dw
DE-sf
DE-sd-ld
DE-sd
DE-rs
MM-mc
MI-kbs
MI-di
DO-pl-mo
ES-sc
DO-pl-mo-se
DO-pl-mo
DE-sd-ld
DO-pl-mo-se
DE-wb
DE-sd-ld
DE-sd-ld
DE-sd
DE-sd-ld
DE-sd-ld
DE-rs
EW-dp
DE-sd-ba
EW-ha
ES-bm
DE-st-sfa
DE-sd
DE-sd-ld
EW-ha
ES-wb
DE-st-sfa
DE-sd
DE-st-sfa
DE-sd
DE-sd
15°
15°
10°
5°


DA-aa
DA-af
EW-ha
ES-wb
MT-sc
DE-sd-ld
DE-sd
EW-dp
DO-pl-mo
ES-sc
DC-ta
MV-lf
MR-eb
MT-ed
MV-np
MV-blf
MV-cf
MV-lf
EW-dp
DE-sd
EW-dp
ES-wb
DO-pl-mo-se
DE-sd-ld
ES-rh-co
DE-sd
EW-ha
DE-sd-ld
DE-sd
DE-sd-ld
EW-dp
DE-sd
DE-sd-ld
ES-bm
DE-scw
ES-wb
EW-ha
DC-ta
EW-ha
ES-wb
EW-ha
ES-wb
DA-aa
DA-af
DA-bcw
ES-wb
ES-rh-co
DE-rs
EW-dp
DE-sf
DE-sd
EW-ha
ES-wb
MALI
MT-fv
MR-eb
MR-gr
DA-aa
DA-af
ES-wb
DE-sd
DE-sd
DE-sd-ld
DE-sd
DE-sd
EW-ha
ES-wb
DE-sd-ld
EW-dp
ES-rh-co
ES-rh-co
DE-wb
DE-st-
EG-si
Tombouctou
Niger
River
DA-de
DE-st-sfa
EG-si
DE-sd
DE-sd
ES-rh-co
ES-rh-co
DE-sd
EW-ha
ES-wb
DA-ms
DA-ifl
DA-lfd
DA-obl
DA-ac
DA-nl
DA-bs
SCALE IN MILES
100
0
100
200
5°
0°
5°


MV-lf
EW-dp
DA-af
ES-ol
MV-lf
ES-wb
DC-ta
DE-sd
DE-sd
DE-sd
MR-eb
MV-cc
MV-lf
DA-bcw
DA-aa
DA-af
ES-wb
MV-lf
MV-np
MV-np
MV-cc
FORT LAPERRINE
ES-cc
EW-ha
MT-sc
ES-wb
DC-ta
ES-rh-co
ES-bm
EW-ha
EW-ha
ES-wb
DC-ta
ES-bm
DE-scw
ES-wb
EW-ha
20°
MV-cc
MV-lf
CA-af
DA-aa
DE-sd-ld
DE-sd
DE-sd
MV-cc
MV-lf
MV-cc
MV-lf
N I G E R
ES-sc
Agades
MR-hc
MT-sc
DE-st-sfa
DE-sd-ld
EW-dp
DE-rs
DE-sd
DE-sd-ld
DE-sd
DE-sd-ld
EW-dp
DE-rs
DE-sd
DE-sd
15°
EG-si
EW-fsp
EG-si
Lake
Chad
DE-sd
NIGERIA
5°
10°



Natural levees.....DA-nl
Oxbow lakes.....DA-obl
Salt lakes.....DA-sl

COLLUVIAL

Talus.....DC-ta

EOLIAN

Duet pits.....DE-dp
Rippled surfaces.....DE-rs
Sand dunes (undiff.).....DE-sd
Barchans.....DE-sd-ba
Complex dunes.....DE-sd-cd
Peak and fulji.....DE-sd-pf
Traneverse dunes.....DE-sd-td
Dune massifs.....DE-sd-dm
Longitudinal dunes.....DE-sd-ld
Sand-choked wadis.....DE-scw
Silt flats.....DE-sf
Stabilized or partly stabilized sand areas
Stabilized free or active forms.....DE-st-sfa
Waves and billows.....DE-wb

MARINE

Beaches.....DM-be

ORGANIC-CHEMICAL

Caliche.....DO-ca
Playas (undiff.).....DO-pl
Dry.....DO-pl-dr
Moist (undiff.).....DO-pl-mo
Clay encrusted.....DO-pl-mo-ce
Salt encrusted.....DO-pl-mo-se
Salt marsh.....DO-sm

II. EROSIONAL

GROUND WATER

Karst topography.....EG-ka
Sinks.....EG-si

MARINE

Wave-cut cliffs.....EM-wcc
Wave-cut terraces.....EM-wct

Scarps.....ES-ec
Steep wadi banks.....ES-wb

WIND

Desert pavement (undiff.).....EW-dp
Flint-strewn plains.....EW-fep
Hamadas.....EW-ha
Stabilized or partly stabilized areas
Blowouts.....EW-st-bl

III. MISCELLANEOUS

INTRUSIVE

Dikes.....MI-di
Knobs.....MI-kbs

METEORIC

Meteor craters.....MM-mc

RESIDUAL

Exfoliated boulders.....MR-eb
Grus.....MR-gr
Heat cracks.....MR-hc

TECTONIC

Basin ranges.....MT-br
Domal warps.....MT-dw
Elongate domes.....MT-ed
Fault valleys.....MT-fv
Intramontane valleys.....MT-iv
Scarps.....MT-sc

VOLCANIC

Broken lava flows.....MV-blf
Cinder cones.....MV-cc
Cinder fields.....MV-cf
Lava flows.....MV-lf
Necks and plugs.....MV-np

*The colors used on the maps have been restricted to the most common landforms which occur at Yuma. Areas so delineated in Northwest Africa indicate regions within which the particular landform predominates. Landform types DA-bs, DA-bcw, DC-ta, ES-wb, ES-dw, DA-nl, and DA-ma occur at Yuma but are of relatively minor areal extent and have not been mapped.

EW-kh or DA-de — Indicates the general area in which a specific landform or surface condition is known to exist.

EW-kh — Indicates that this feature is common or widespread throughout the physiographic unit within which the designation lies.

ES-wh — Indicates a specific location of a landform

ANALOGS OF YUMA TERRAIN IN THE NORTHWEST AFRICAN DESERT

SELECTED LANDFORMS AND SURFACE CONDITIONS

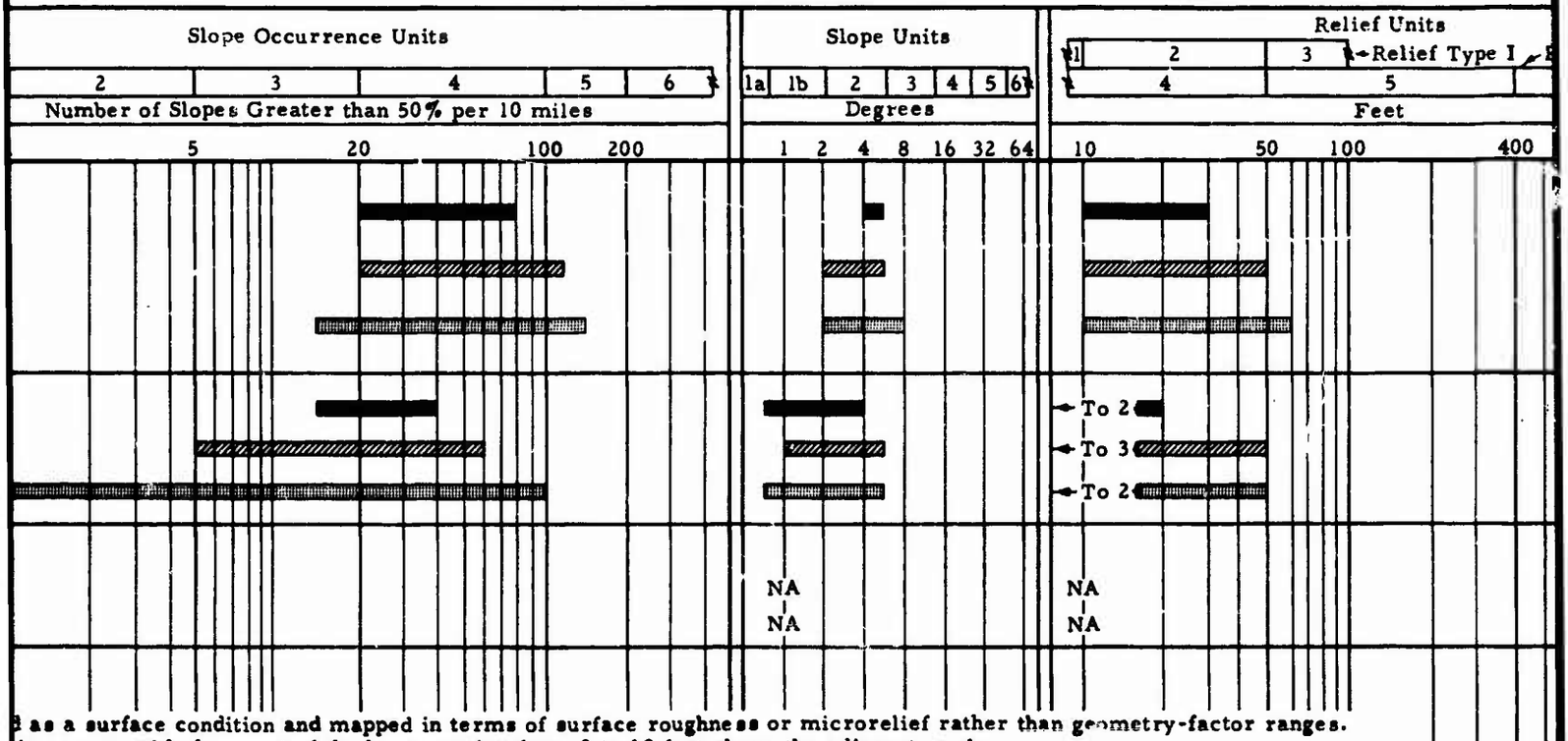
PLATE 18

Photo No.	CLASSIFICATION AND DESCRIPTION	Plan-Profile Units	Range at
	I. DEPOSITIONAL ALLUVIAL		1 2 Number 1
1	Alluvial fans: Alluvial fans are cone-shaped features occurring at the base of mountains, hills, escarpments, etc., where streams experience a sufficient reduction in gradient to deposit their loads. These fans, steepest near the mountains, slope gently outward with a continually decreasing gradient and are characterized by braided stream channels which score their surfaces.	1L 1, 1L 1, 1L	
2	Alluvial aprons: Alluvial aprons are created through coalescence of alluvial fans along the base of mountains or plateau escarpments.	1L, 7 1, 1L, 7 1, 1L, 7	To 0
3	Abandoned courses: Abandoned courses are lengthy segments of a river abandoned when the stream chooses a new course across the floodplain.	NA* NA	NA NA
4	Bars and swales: Bars and swales are a series of alternating sandy ridges (bars) and arcuate clay or silt-filled sloughs (swales) developed on the inside of a meander bend of a river which grows by the slow addition of individual accretions accompanying migration of the meander.	This phenomenon is classed as a surf These surfaces are rolling in nature,	
5	Boulder-choked wadies: Boulder-choked wadies are relatively narrow and deep, intermittent streambeds, generally in mountainous or plateau regions, where boulders have been amassed in numbers sufficient to retard or prevent vehicular movement.	NA NA	NA NA
6	Deltas: Deltas are alluvial tracts of land, usually triangular in shape, formed at the mouth of a river. Inland boundaries of deltas often, but not invariably, coincide with the farthest upstream distributaries of a river.	7 7	Lacking Lacking
7	Floodplains: Floodplains are relatively smooth, flat lands bordering a stream. They are built of sediments deposited by the stream and inundated by floodwaters.	7 1, 7 1, 1L, 7	Lacking To 0 To 0
8	Intermittent freshwater lakes: Intermittent freshwater lakes are standing bodies of inland fresh water which become dry during certain periods of the year.	NA NA	NA NA
9	Intermontane plains: Basins of interior drainage between mountain ranges composed of fine-grained alluvium deposited by streams issuing from the adjacent mountains.	1, 7 1, 1L, 7	To 0 To 0
10	Levee-flank depressions: Levee-flank depressions are irregular to rectilinear low areas, usually containing ponds or lakes, paralleling and flanking natural levee ridges. They are best developed in deltaic regions.	NA NA	NA NA
11	Marsh: Marsh is a tract of low (in reference to surrounding terrain), wet ground, usually miry and covered with rank grass and sedge vegetation and confined to freshwater areas.	This phenomenon is classed as a surf Marshes are characteristically featu	

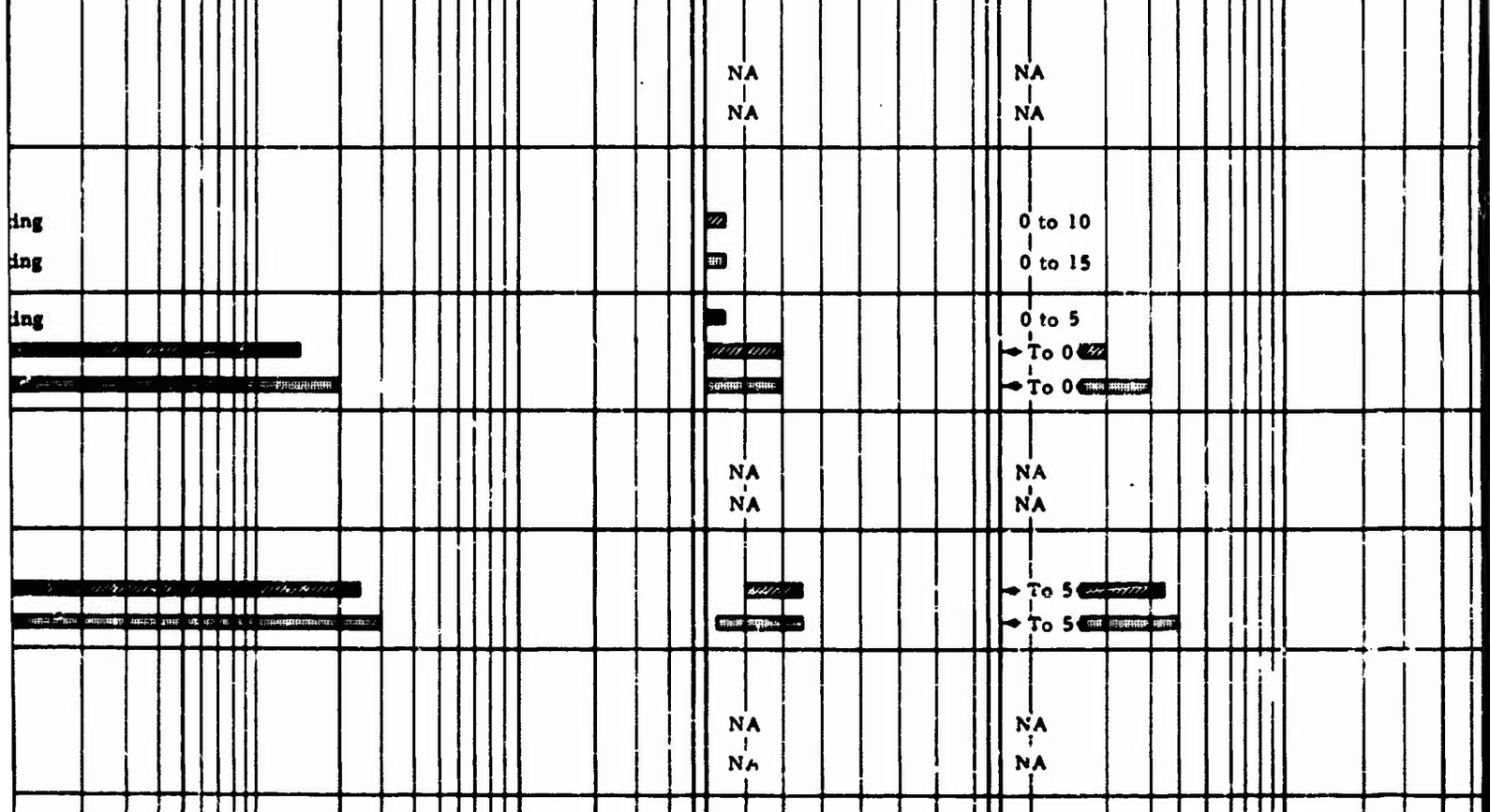
2

LANDFORMS—SURFACE CONDITIONS: DE

Range at Yuma Range in Northwest African Desert Worldwide Range



as a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
in nature, with the crest of the bars ranging from 2 to 10 feet above the adjacent swale.



as a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
ally featureless.

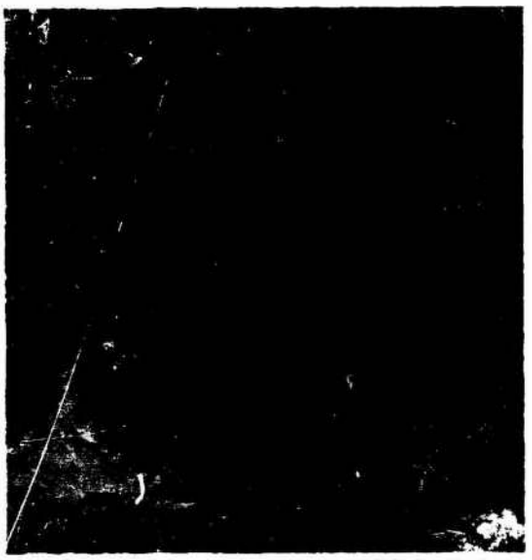
3

DESCRIPTIONS AND PHOTOGRAPHS

Type I — Relief — Type II

	6	7

400 1000

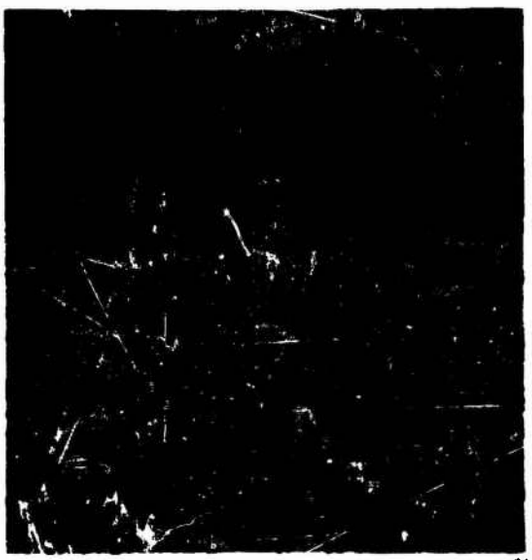


U. S. Army Map Service

1. A vertical photograph of an alluvial fan

U. S. National Park Service

2. An alluvial apron forming a narrow, continuous band between the background mountains and the basin in the lower half of the photograph



F. C. Schrader, USGS[24]

5. Boulder-choked wadis

U. S. Army Engineer District, New Orleans

6. Present distributary system of the Mississippi River Delta

Shell[9]

U. S. Army Corps of Engineers

U. S. National Park Service

narrow, contin-
und mountains
of the photograph

U. S. Army Corps of Engineers

3. A vertical photograph showing the now heavily vegetated meander of an abandoned course in the lower left quarter of the photograph

U. S. Army Corps of Engineers

4. A vertical photograph of bar and swale topography. The bars are the light arcuate areas, the swales the intervening dark, vegetated areas

gineer District, New Orleans

ystern of the
Delta

Reference 18

7. Floodplain of the Colorado River, looking southward from Laguna Dam, Arizona

U. S. Army Corps of Engineers

8. Intermittent freshwater lakes

S. Army Corps of Engineers

G. R. Gross, U. S. National Park Service

U. S. Army Engineer District, New Orleans

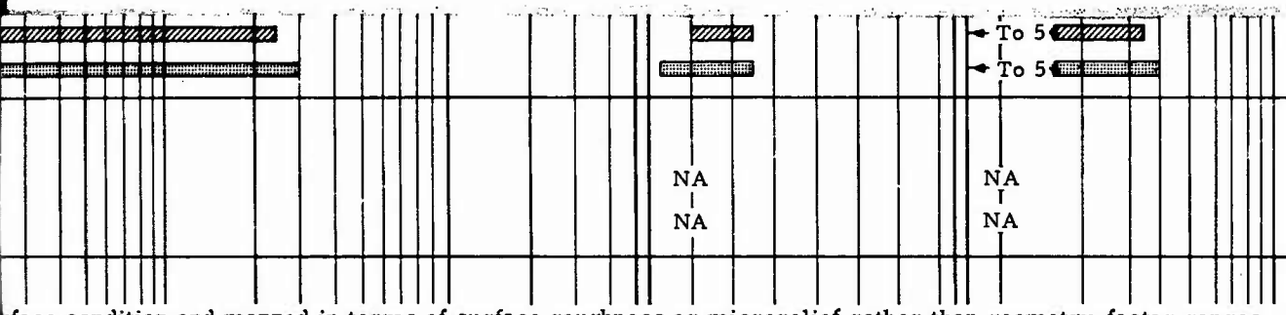
9	tain ranges composed of fine-grained alluvium deposited by streams issuing from the adjacent mountains.	1, 7 1, 1L, 7	←To 0 ←To 0
10	Levee-flank depressions: Levee-flank depressions are irregular to rectilinear low areas, usually containing ponds or lakes, paralleling and flanking natural levee ridges. They are best developed in deltaic regions.	NA NA	NA NA
11	Marsh: Marsh is a tract of low (in reference to surrounding terrain), wet ground, usually miry and covered with rank grass and sedge vegetation and confined to freshwater areas.	This phenomenon is classed as a surf Marshes are characteristically featur	
12	Natural levees: Natural levees are long, relatively narrow alluvial ridges, higher near the river and gradually sloping away from it, which are built up on either side of a stream by overbank flow. Surface drainage patterns range from minute drainageways to major crevasses, commonly found at right angles to the direction of levee elongation.	NA NA	NA NA
13	Ox-bow lakes: Ox-bow lakes are crescent-shaped lakes formed when rivers are shortened by the coalescence of migrating river bends at the upstream and downstream arms of meander loops.	NA NA	NA NA
14	Salt lakes: Salt lakes are any standing bodies of inland water, generally of considerable size, which contain a predominating amount of sodium chloride in solution and usually magnesium chloride as well as magnesium and calcium sulfate.	NA NA	NA NA
	COLLUVIAL		
15	Talus: Talus is an unconsolidated, sloping heap of fairly large rock fragments or debris formed at the base of an escarpment or steep slope through gravitational accumulation.	NA NA	NA NA
	EOLIAN		
16	Dust Pits: Dust pits are roughly circular depressions which are loosely filled with fine dust or ash-colored powder to the level of the surrounding terrain.	This phenomenon is classed as a surf The surfaces of these pits have low-b	
17	Rippled surfaces: Washboardlike surfaces caused by the heaping up of sand by wind action. They are normally found on the gentler slopes of dunes or in flat, sandy areas.	This phenomenon is classed as a surf Ripples range in height from 1 or 2 in	
	Sand dunes: Sand dunes are mobile heaps of windblown sand independent of fixed objects or underlying topography.		
18	Barchans: Barchans are dunes having a crescentric ground plan with the convex side facing the wind and horns extending leeward. The profile is asymmetric with the gentler slope on the convex side and the steeper slope on the concave or leeward face.	4 4, (5, 6)** 4, (5, 6)	

* Not applicable.

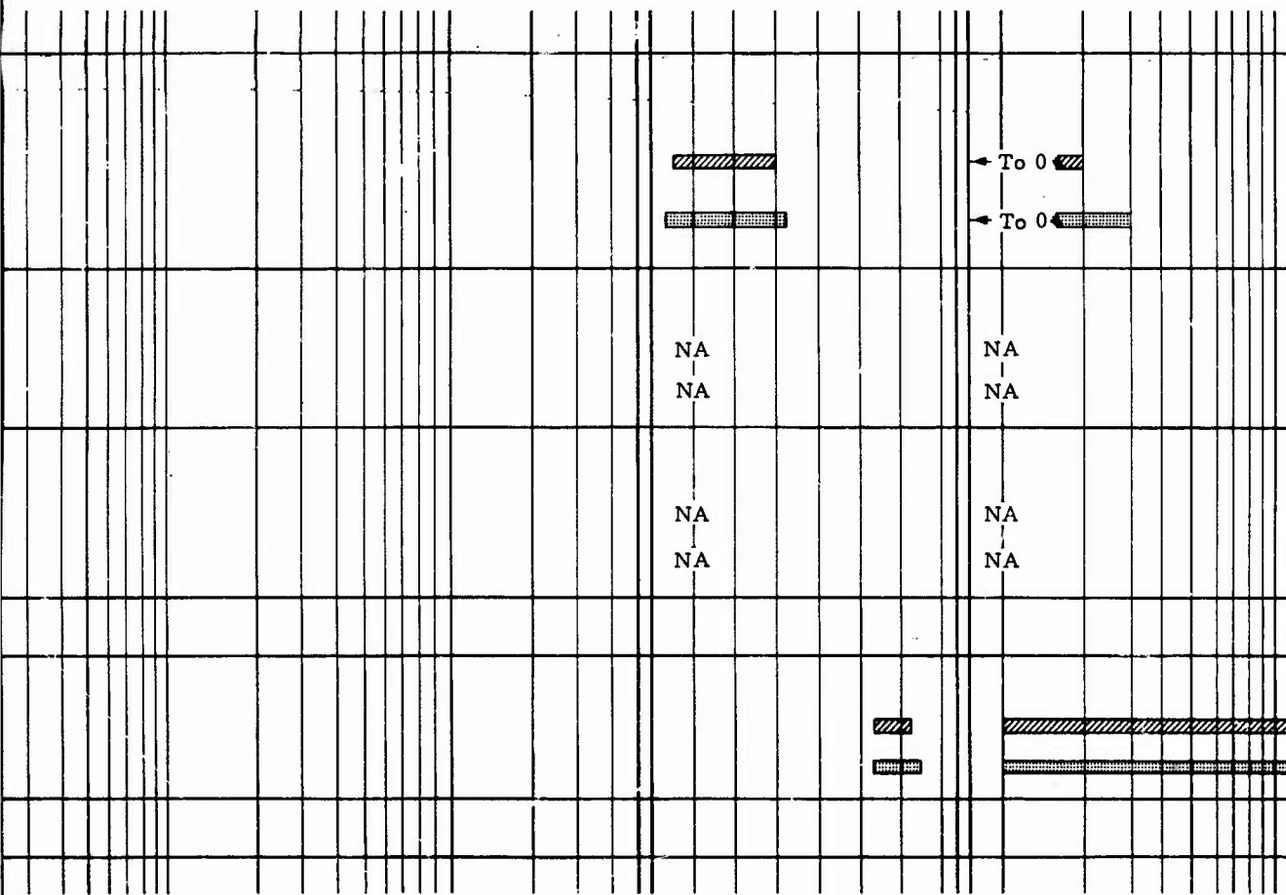
** Circled numbers indicate the plan and profile are both gross and restricted for worldwide conditions but only gross for

† Raised numbers refer to similarly numbered entries in the photographic bibliography at the end of volume I of this repo

5

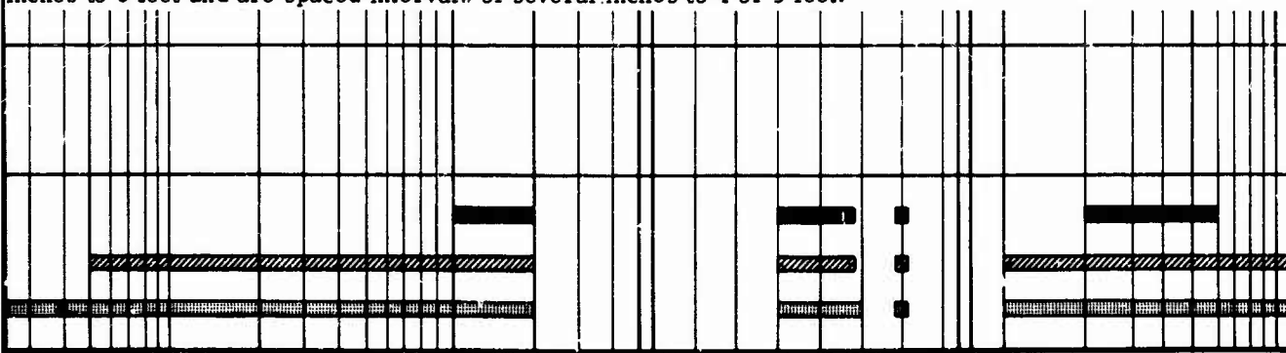


rface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
ureless.



rface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
-bearing capacities.

rface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
inches to 3 feet and are spaced intervals of several inches to 4 or 5 feet.



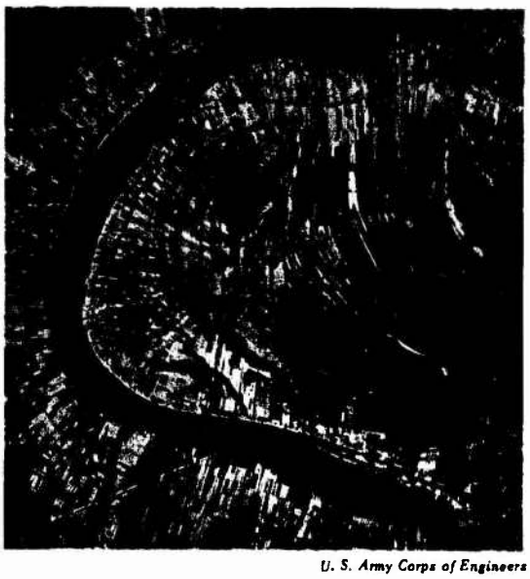
Northwest Africa.
ort.

Shell[9]

9. Intermontane plain as viewed from adjacent mountain

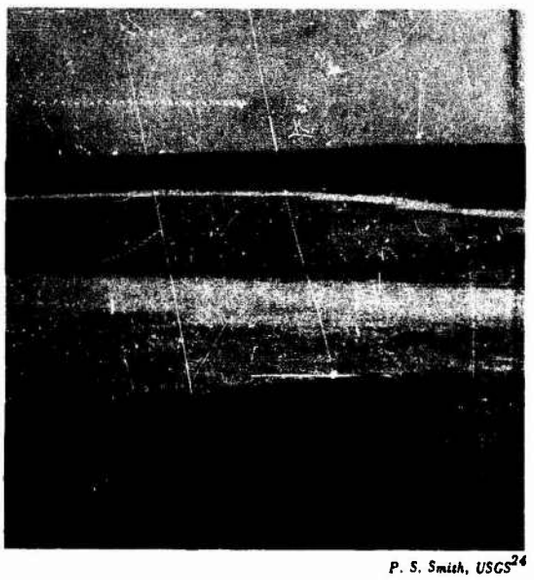
U. S. Army Corps of Engineers

10. Water-filled levee-flank depressions



U. S. Army Corps of Engineers

13. A vertical photograph of an oxbow lake — False River Cutoff, Louisiana

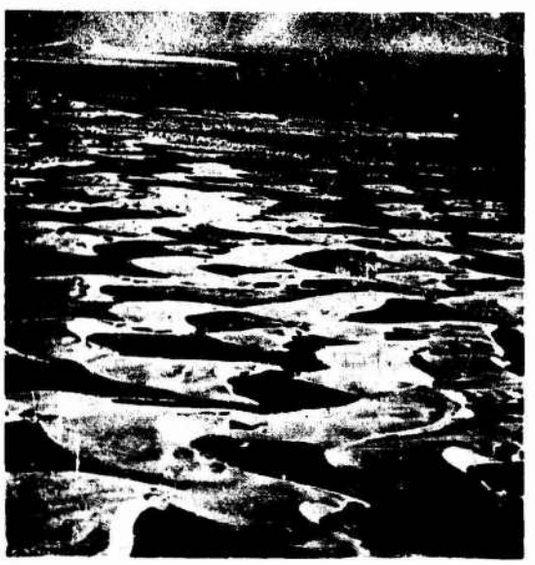


P. S. Smith, USGS[24]

14. A salt lake fringed by white, crystallized salt

Atlas Photographique D'Algérie[9]

17. Rippled surfaces

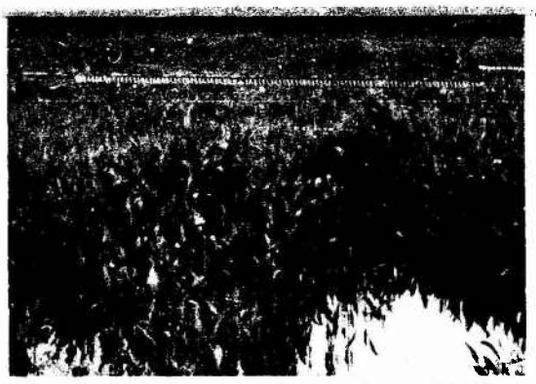


Reference 8

18. A field of barchan dunes north of Magdalena Bay, Mexico

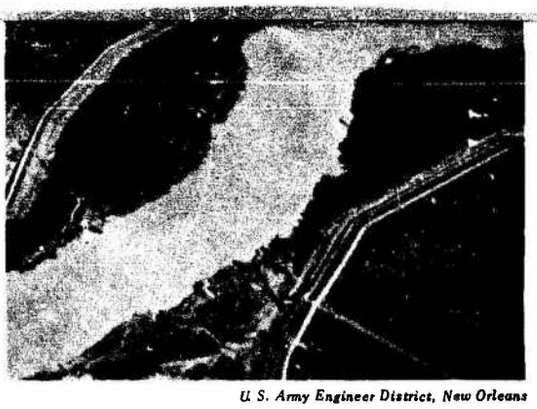
Army Corps of Engineers

depressions



G. R. Grant, U. S. National Park Service

11. Marsh



U. S. Army Engineer District, New Orleans

12. Cultivation on natural levees

P. S. Smith, USGS[24]

by white,

W. H. Jackson, USGS[24]

15. Steeply sloping talus cone flanking a plateau escarpment

NO PHOTOGRAPH AVAILABLE

16. Dust pits

Reference 8

ner north of
xico

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

LANDFORMS - SURFACE CONDITIONS

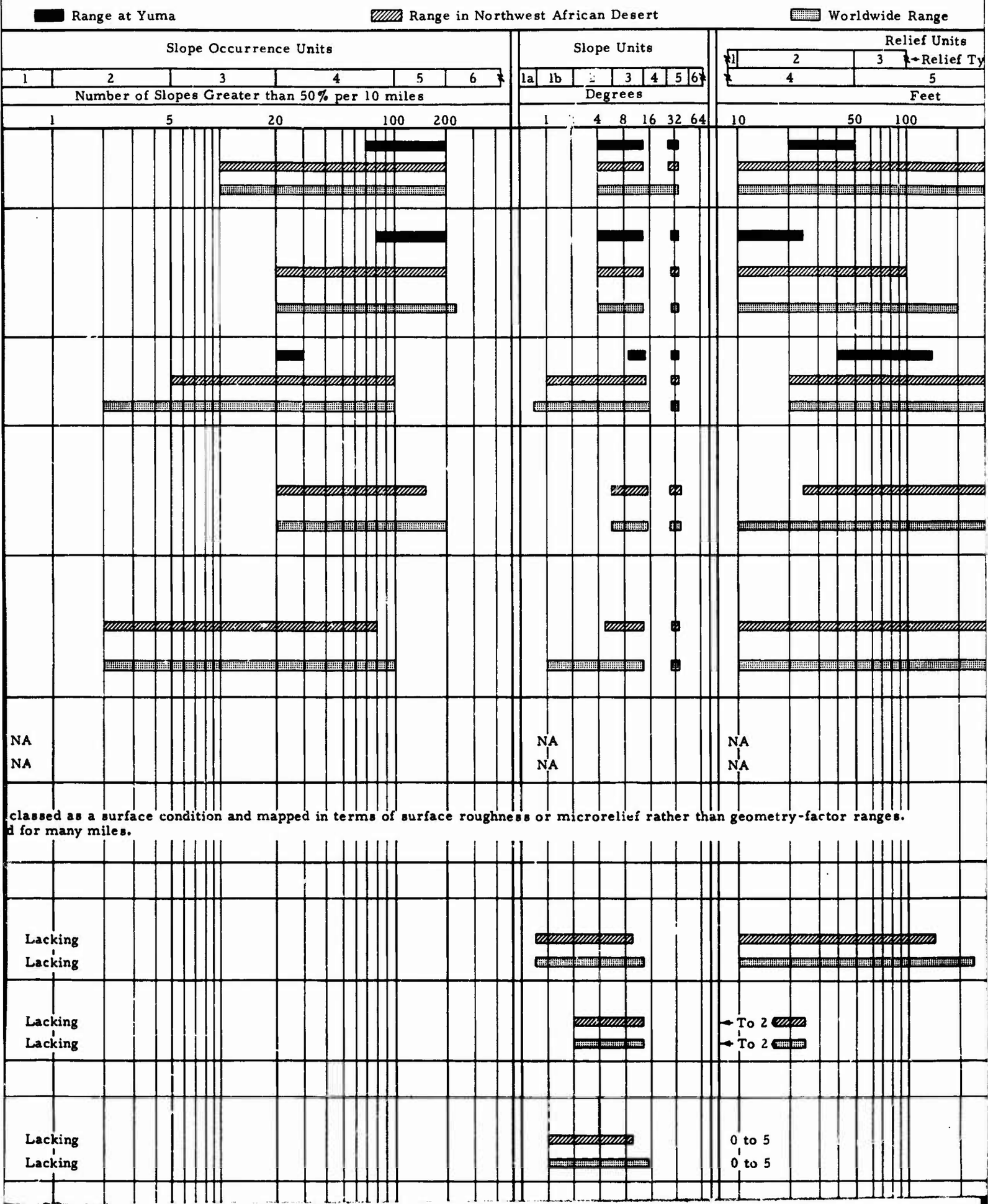
DESCRIPTIONS AND PHOTOGRAPHS

PLATE 19

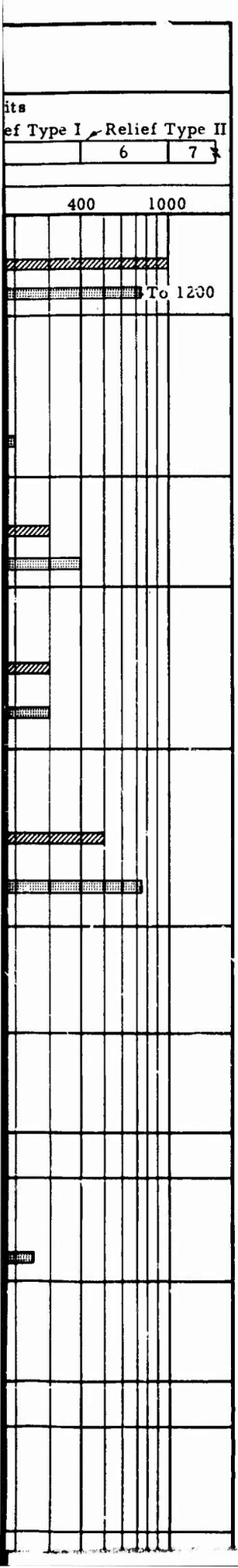
8

Photo No.	CLASSIFICATION AND DESCRIPTION	Plan-Profile Units	Range a
	I. DEPOSITIONAL (CONT.) EOLIAN		1 | 2 Numbe 1
19	Complex dunes: Complex dunes are irregular masses of sand not readily classifiable into types.	4 4, (5L//, 6L, 6L//) (4, 4L, 5, 5L, 5//, 5L//, 6, 6L, 6//, 6L//)	
20	Peak and fulji: These occur where the tips or horns of a fast-moving barchan join or intersect the windward side of another barchan, thus forming a circular or horseshoe-shaped hollow known as a fulji. The crest of the barchan slipface, which flanks the fulji, is referred to as the peak.	4 4 (4)	
21	Transverse dunes: Transverse dunes are strongly asymmetric ridges extending transverse to the direction of dominant sand-moving winds. The leeward slope is steep; the windward, comparatively gentle.	4L// 4L//, (5L, 6L) (4L, 4L//, 5L, 5L//, 6L, 6L//	
22	Dune massifs: Dune massifs are massive, roughly conical or pyramidal dunes characterized by curved slopes. Small hollows and terraces often dimple their steep sides. The massifs are usually associated with longitudinal dunes, but are quite unmistakable as they rise far above the general crest level.	4 4	
23	Longitudinal dunes: Longitudinal dunes usually consist of a single continuous ridge which swells and rises at regular intervals to form a chain of summits connected by a continuous wavy cre . The profile is asymmetric with one side exhibiting a moderate slope; the other, a steep or slipface. Longitudinal dunes are aligned parallel to dominant sand-moving winds.	4L//, (5L//, 6, 6L, 6L//) (4L, 4L//, 5L, 5L//, 6, 6L, 6L//	
24	Sand-choked wadis: Sand-choked wadis are intermittent streambeds generally within plain or plateau areas which have been almost completely or partly filled with windblown sand.	NA* NA	NA NA
25	Silt flats: Silt flats are almost flat surfaces composed of silt generally swept clean by wind action.	This phenomenon is classed as a sur Silt flats ...en extend for many miles	
	Stabilized or partly stabilized sand areas.		
26	Stabilized free or active forms: Active dune types which have been stabilized by vegetation but which still retain their initial form.	(5L//, 6, 6L, 6L//) (4, 4L, 4L//, 5, 5L, 5L//, 6, 6L, 6L//	Lacking Lacking
27	Waves and billows: Waves and billows are undulating to rolling areas of sand which present a surface not unlike the waves of a rough sea.	4, 7 4, 7	Lacking Lacking
	MARINE		
28	Beaches: Beaches are gently sloping strips of land bordering the sea, usually recognized as that part which lies between high- and low-water marks and formed by the action of the sea.	7 7	Lacking Lacking
	ORGANIC-CHEMICAL		

LANDFORMS — SURFACE CONDITIONS:



: DESCRIPTIONS AND PHOTOGRAPHS



U. S. Army Map Service

19. A vertical photograph of a complex dune field in Algeria

U. S. Army Office of Quartermaster General[23]†

20. Peak and fulji topography in the Yuma Sand Hills, Arizona

H. J. L. Beadnell[4]

23. The sinuous crest line of a longitudinal dune

Institut Géographique National, France[14]

24. Sand-choked wadis appear as white bands which weave through the highly dissected plateau

Wilfred Thesiger[3]

Shell[9]

...artermaster General[23] †

...in the Yuma

Fairchild Aerial Surveys, Inc.[22]

21. Transverse dunes in the vicinity of Delta, Utah

J. Saigot[9]

22. Dune massifs separated by sandy plains

...se National, France[14]

...r as white
...e highly

NO
PHOTOGRAPH
AVAILABLE

25. Silt flat

U. S. Forest Service

26. Stabilized sand dune area

Shell[9]

U. S. Soil Conservation Service, Department of Agriculture

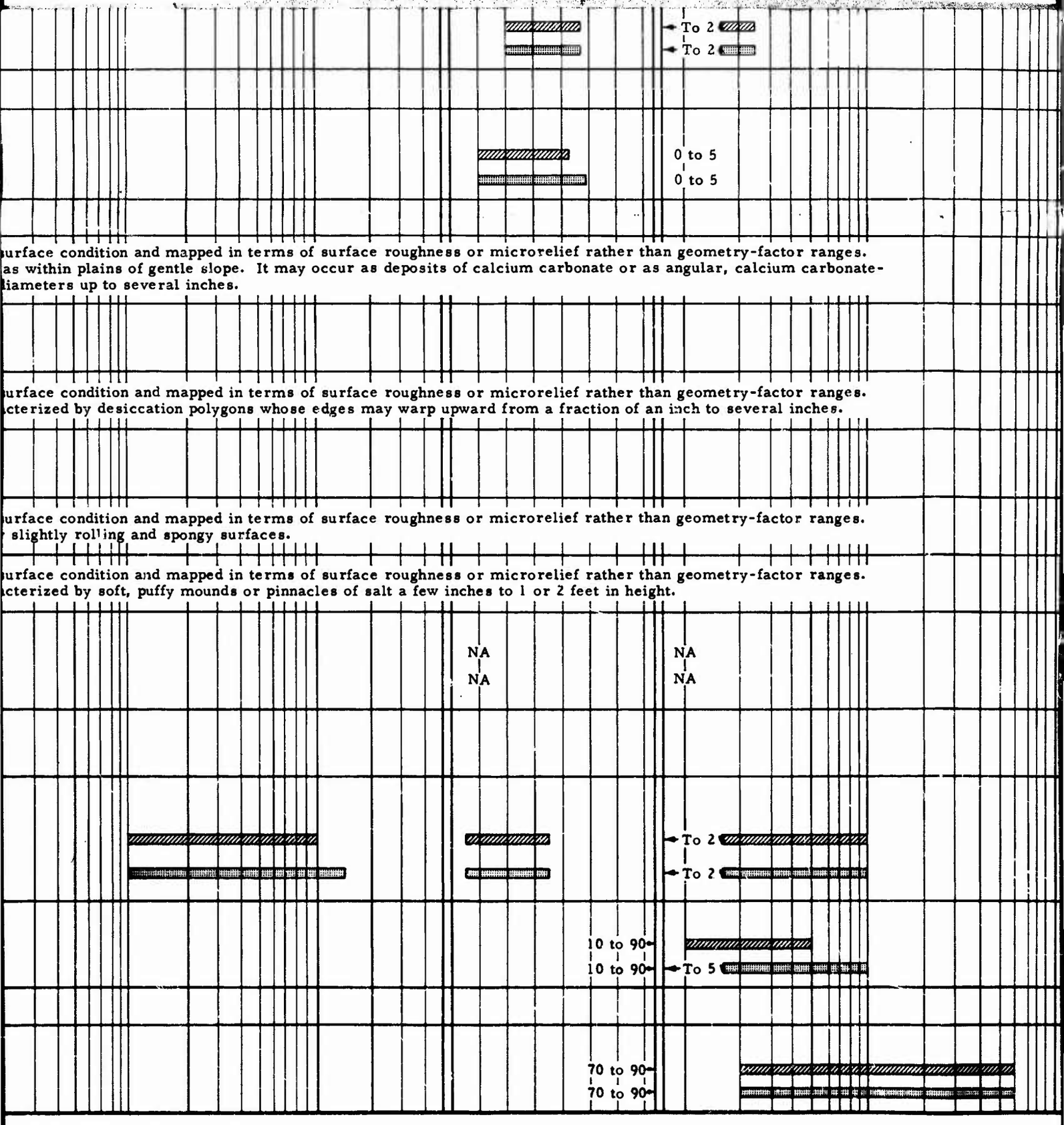
R. O. Stone

27	Waves and billows: Waves and billows are undulating to rolling areas of sand which present a surface not unlike the waves of a rough sea.	4, 7 4, 7	Lacking Lacking	
	MARINE			
28	Beaches: Beaches are gently sloping strips of land bordering the sea, usually recognized as that part which lies between high- and low-water marks and formed by the action of the sea.	7 7	Lacking Lacking	
	ORGANIC-CHEMICAL			
29	Caliche: Caliche is a calcareous deposit occurring at or near the surface, which has accumulated from charged ground-water moving upward and evaporating.	This phenomenon is classed as a surf Caliche occurs in most desert areas v cemented fragments of rock with diam		
	Playas: Playas are nearly flat areas of salt or salty fine-grained soils occupying basins where water collects and evaporates after moderate or torrential rains.			
30	Dry playas: Dry playas are characterized by very hard, smooth, flat surfaces of fine-grained soil.	This phenomenon is classed as a surf Surfaces of these playas are characte		
	Moist playas: Moist playas are characterized by irregular, puffy surfaces with a thin friable surface crust which is underlain by soft, spongy ground.			
31	Clay-encrusted playas: Clay-encrusted playas are moist playas with a surface crust of clay.	This phenomenon is classed as a surf These playas are characterized by sli		
32	Salt-encrusted playas: Salt-encrusted playas are moist playas with a surface crust of salt.	This phenomenon is classed as a surf Surfaces of these playas are characte		
33	Salt marsh: A salt marsh is a flat, poorly drained part of a coastal region whose surface is so near the level of the mean high tide that it is covered by the majority of high tides.	NA NA	NA NA	
	IL EROSIONAL GROUNDWATER			
34	Karst topography: Karst topography is developed in limestone regions by the solution action of ground and surface waters. In advanced stages, the topography is irregular and characterized by numerous sinks and depressions of all sizes interspersed with abrupt ridges and irregular protuberant rocks.	1 1		
35	Sinks: Sinks are circular or elongate depressions of varying size formed by solution and collapse in areas of calcareous or evaporite rock.	NA NA	NA NA	
	MARINE			
36	Wave-cut cliffs: Steep cliffs of bare rock, or occasionally unindurated materials, resulting from wave action marking the seaward limit of the coast.	NA NA	NA NA	

* Not applicable.

** Circled numbers indicate the plan and profile are both gross and restricted for worldwide conditions but only gross for

† Raised numbers refer to similarly numbered entries in the photographic bibliography at the end of volume I of this repo



urface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
as within plains of gentle slope. It may occur as deposits of calcium carbonate or as angular, calcium carbonate-
liameters up to several inches.

urface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
cterized by desiccation polygons whose edges may warp upward from a fraction of an inch to several inches.

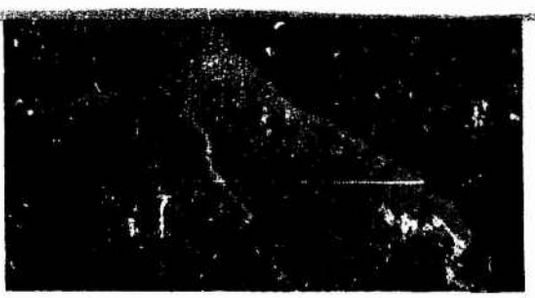
urface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
slightly rolling and spongy surfaces.

urface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
cterized by soft, puffy mounds or pinnacles of salt a few inches to 1 or 2 feet in height.

or Northwest Africa.
port.

Wilfred Thesinger[3]

27. Sand waves and billows rising above a sandy plain



Shell[9]

28. A narrow beach bounded by the vegetated coastal plain and the sea

R. O. Stone

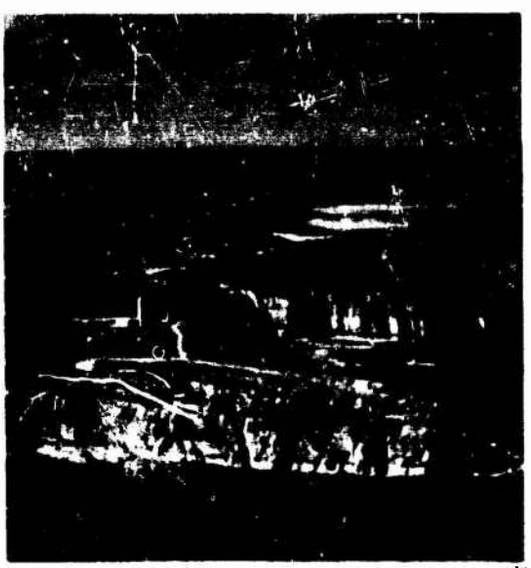
31. Soft and spongy surface of a clay-encrusted playa

La Belle Image[9]

32. Rough surface of a salt-encrusted playa

Darrow, USGS[14]

35. A sink as viewed from the rim



Institut Géographique National, France[14]

36. Wave-cut cliffs

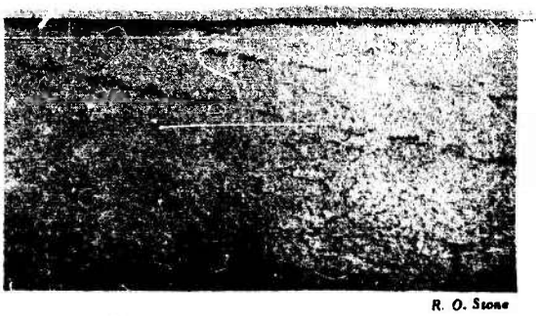
7

Shell[9]

y the vege-
e sea

U. S. Soil Conservation Service, Department of Agriculture

29. The light-colored caliche is overlain by a dark sandy clay layer



R. O. Stone

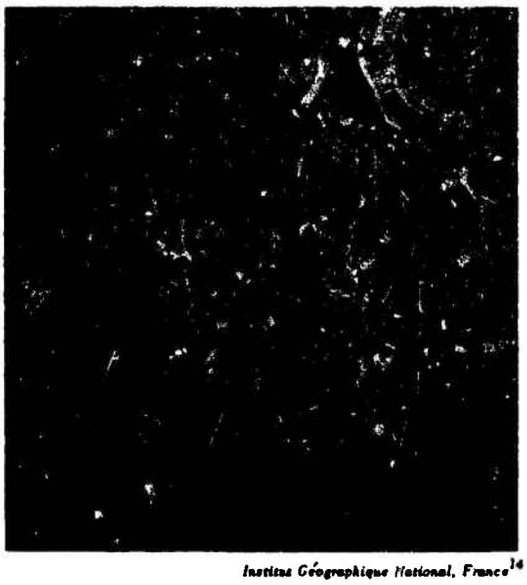
30. Desiccation cracks on the surface of a dry playa

La Belle Image[9]

ncrusted

V. J. Chapman[7]

33. Salt marsh



Institut Géographique National, France[14]

34. A vertical photograph of Karst topography in a limestone plateau area

National, France[14]

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

LANDFORMS - SURFACE CONDITIONS

DESCRIPTIONS AND PHOTOGRAPHS

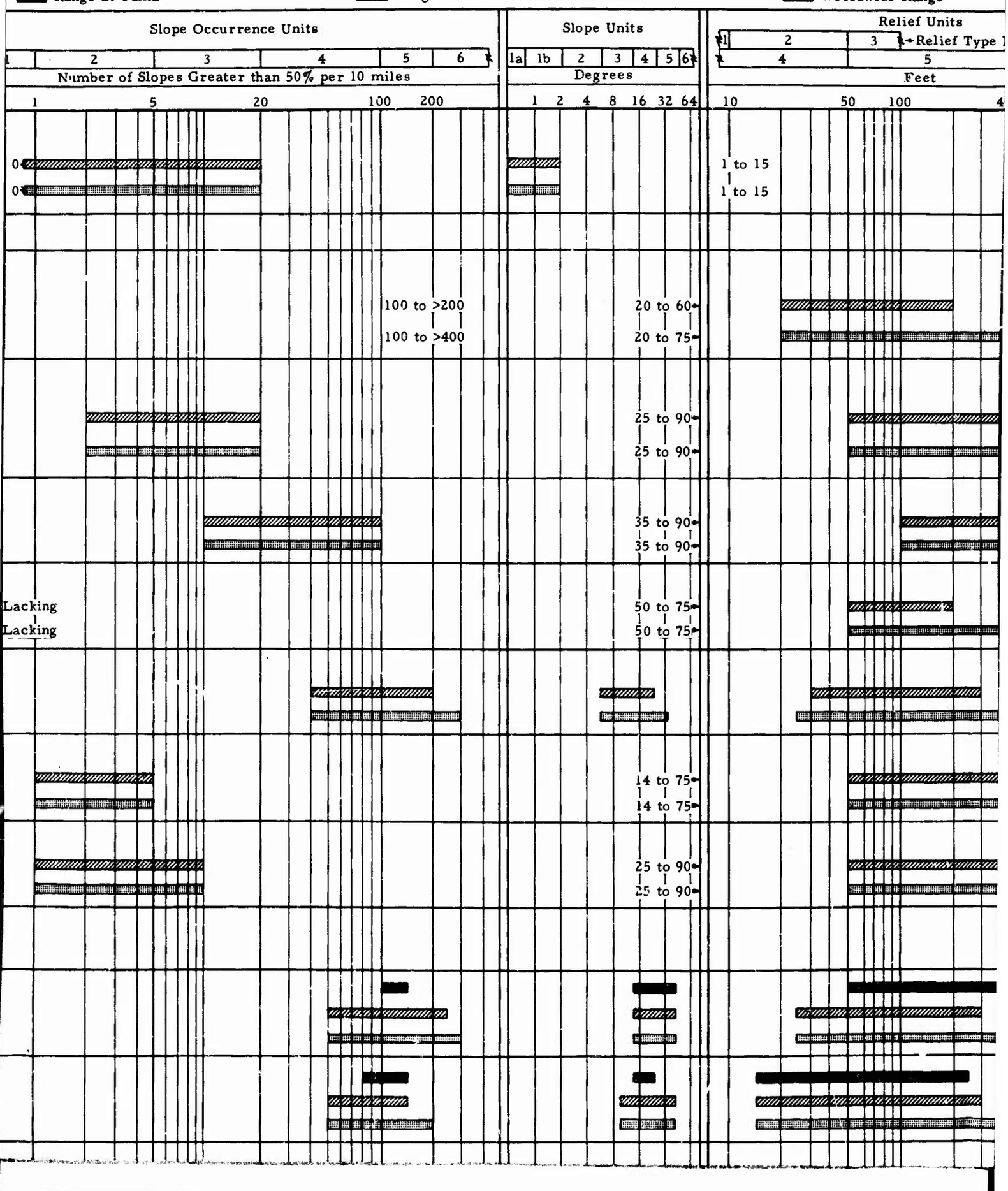
PLATE 19A

4 8

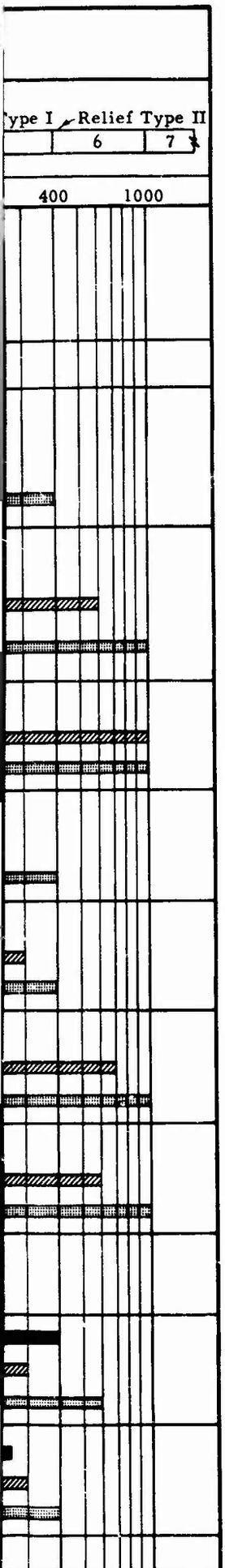
5 1

Photo No.	CLASSIFICATION AND DESCRIPTION	Plan-Profile Units	Range — Numb 1 2
	II. EROSIONAL (CONT.) **MARINE**		
37	**Wave-cut terraces:** Steplike, narrow strips of land adjacent to or near the sea which have been sculptured by the waves and current. Each terrace records a landward advance of littoral erosion.	1, 7 1, 7	To 0 To 0
	SURFACE WATER		
38	**Badlands:** Regions nearly devoid of vegetation where erosion, instead of carving hills and valleys of the ordinary type, has cut the land into an intricate maze of narrow ravines, sharp crests, and pinnacles.	4 4	
39	**Buttes and mesas:** Isolated residual prominences with very steep or precipitous slopes left as erosional remnants of a plateau area. Mesas have distinctively flat tops; buttes have been so eroded that only small flat tops or peaks remain.	(2, 3, 5, 6)** (2, 2//, 3, 3//, 5, 5//, 6, 6//)	
40	**Canyon country:** Canyon country refers to a plateau dissected by a branching network of broad, steep-walled valleys.	(1, 1L, 2) (1, 1L, 2, 4, 5)	
41	**Flatirons:** Triangular remnants of an eroded hogback ridge often occurring in series on the flank of a mountain.	7 7	Lacking Lacking
42	**Foothills:** Foothills are lower subsidiary hills at the foot of mountains or higher hills. They form transitional zones between the highlands and the adjacent lower land.	4, 4L 4, 4L	
43	**Hogbacks:** Hogbacks are sharp-crested ridges produced by unequal erosion in steeply inclined rock.	4L, 4L// (4L, 4L//, 5L//, 6L//)	
44	**Outliers:** Outliers are isolated remnants of rock separated from the main mass to which they were formerly joined.	(3, 6) (3, 6)	
	Random hills: Randomly oriented masses rising less than 1,000 feet above the level of the surrounding country.		
45	**Consolidated random hills:** Consist of masses of sedimentary, igneous, or metamorphic rock.	4 4, 4L 4, 4L	
46	**Unconsolidated random hills:** Consist of unconsolidated material such as clay, silt, sand, or gravel.	4 4, 4L 4, 4L	

LANDFORMS — SURFACE CONDITIONS: D



DESCRIPTIONS AND PHOTOGRAPHS



G. W. Stose, USGS[24] †

37. A wave-cut terrace surmounted by several stacks

J. V. Harrison[12]

38. Badlands

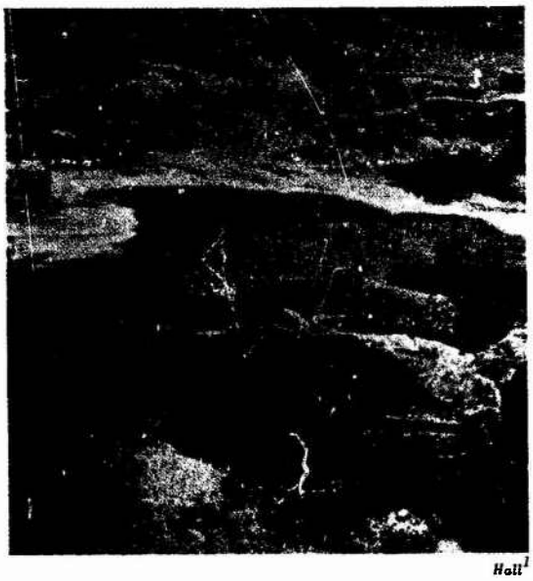
Palace Studios, Boulder, Colorado

41. Flatirons

W. Lindgren, USGS[24]

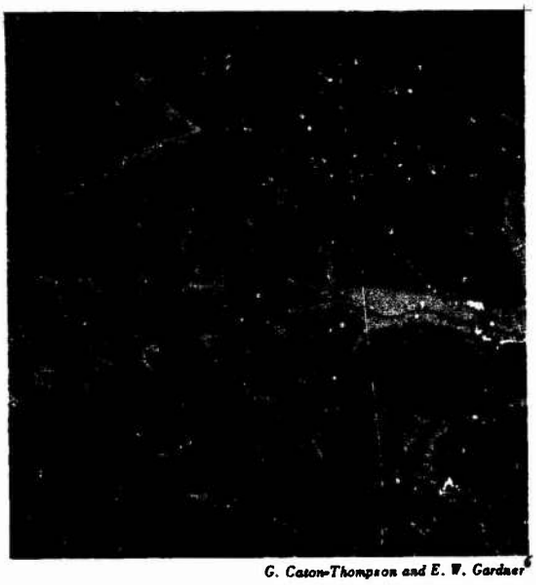
42. Band of foothills at the base of a mountain range

J. V. Harrison[12]



Hall[1]

39. Buttes and mesas



G. Caton-Thompson and E. W. Gardner[6]

40. Canyon country

W. Lindgren, USGS[24]

the base of a
e

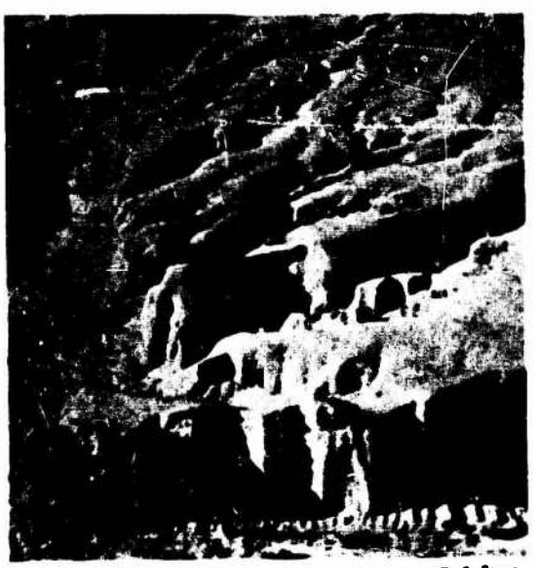
U. S. Soil Conservation Service, Department of Agriculture

43. Hogbacks

The Bon Ami Film Distributing Corp.

44. Outliers

NO
PHOTOGRAPH
AVAILABLE



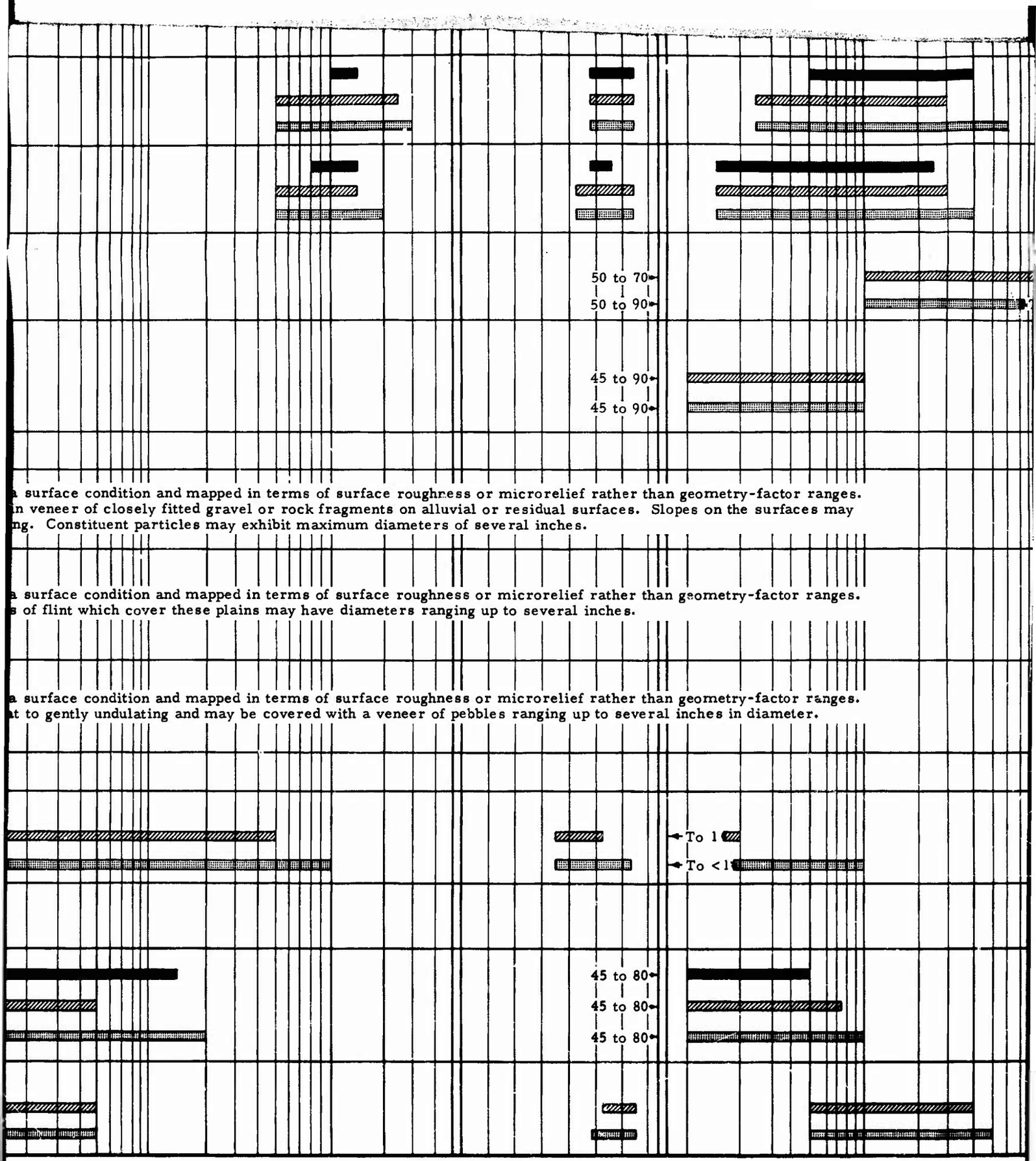
R. O. Stone

	Random hills: Randomly oriented masses rising less [illegible] feet above the level of the surrounding country.			
45	**Consolidated random hills:** Consist of masses of sedimentary, igneous, or metamorphic rock.	4 4, 4L 4, 4L		
46	**Unconsolidated random hills:** Consist of unconsolidated material such as clay, silt, sand, or gravel.	4 4, 4L 4, 4L		
47	**Scarps:** Scarps are more or less continuous, precipitous slopes exhibiting more than 100 feet of relief.	NA* NA	NA NA	
48	**Steep wadi banks:** Steep wadi banks are mapped where a conspicuous number of wadies bordered by high precipitous banks occur. Wherever banks are higher than 100 feet they are considered scarps.	NA NA	NA NA	
	WIND			
49	**Desert pavement:** Desert pavement is a mosaic of closely packed pebbles and broken rock fragments usually coated with a stain of manganese or iron oxide.	This phenomenon is classed as a surf Desert pavement occurs as a thin ven vary from flat to gently undulating. C		
50	**Flint-strewn plains:** Flint-strewn plains are flat to undulating surfaces developed on weathered limestone or chalk. They are characterized by scattered pebbles and sharp-edged chips of flint weathered from parent rock.	This phenomenon is classed as a surf The angular fragments and chips of fl		
51	**Hamadas:** Hamadas are extensive, flat to undulating surfaces of bedrock or bedrock covered by a thin veneer of pebbles or rock fragments.	This phenomenon is classed as a surf The surface of the hamada is flat to g		
	Stabilized or partly stabilized areas			
52	**Blowouts:** Blowouts are saucer-, cup-, or trough-shaped hollows formed by wind erosion on preexisting dune or other sand deposits.	6, 7 4, 5, 6, 7	Lacking Lacking	
	III. MISCELLANEOUS **INTRUSIVE**			
53	**Dikes:** Wall-like intrusions of igneous rock which cut across the bedding or other layered structure of the country rock. On eroding they commonly form narrow, sharp-crested ridges which run for miles across country.	4L 4L, 5L, 6L 4L, 5L, 6L		
54	**Knobs:** Knobs are rounded isolated hills or mountains of plutonic rocks which have cooled and consolidated at some depth and are now exposed by denudation.	4, 5, 6 4, 5, 6		

* Not applicable.

** Circled numbers indicate the plan and profile are both gross and restricted for worldwide conditions but only gross for

† Raised numbers refer to similarly numbered entries in the photographic bibliography at the end of volume I of this repo



a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
n veneer of closely fitted gravel or rock fragments on alluvial or residual surfaces. Slopes on the surfaces may
ng. Constituent particles may exhibit maximum diameters of several inches.

a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
s of flint which cover these plains may have diameters ranging up to several inches.

a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
t to gently undulating and may be covered with a veneer of pebbles ranging up to several inches in diameter.

s for Northwest Africa.
report.

Reference 18

45. Rugged crystalline hills rising above a desert plain

Reference 18

46. Unconsolidated hills near Yuma, Arizona

J. Gilluly, USGS[24]

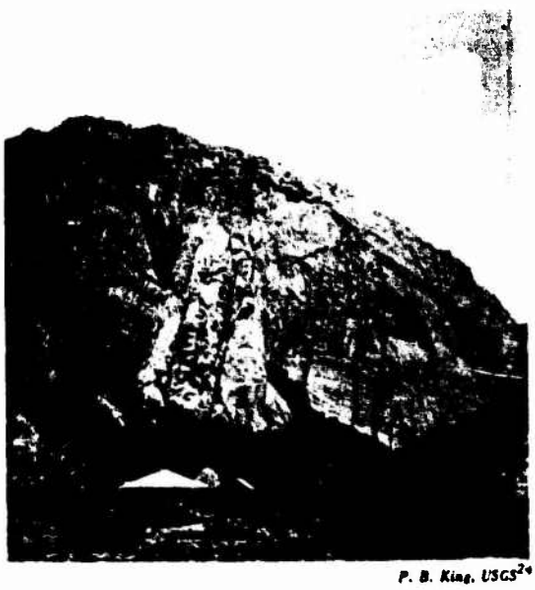
49. A smooth surface of desert pavement. The tire tracks have penetrated the underlying silt

NO PHOTOGRAPH AVAILABLE

50. Flint strewn plain

I. C. Russell, USGS[24]

53. View along a ridge cut by dikes



P. B. King, USGS[24]

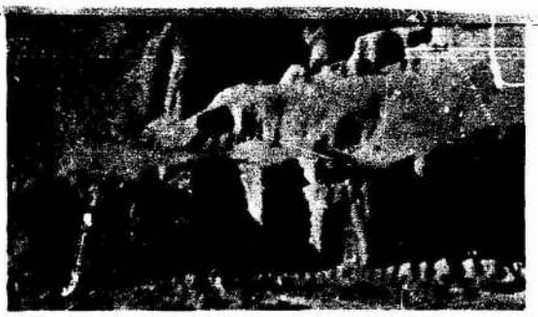
54. A granite knob rising abruptly above a desert plain

Reference 18

Yuma,

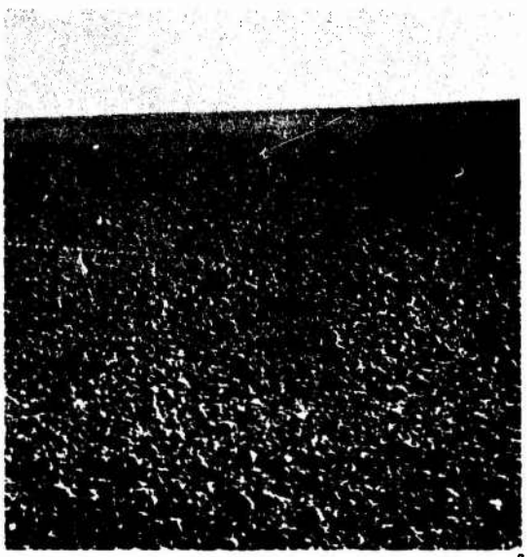
PHOTOGRAPH
AVAILABLE

47. Scarp



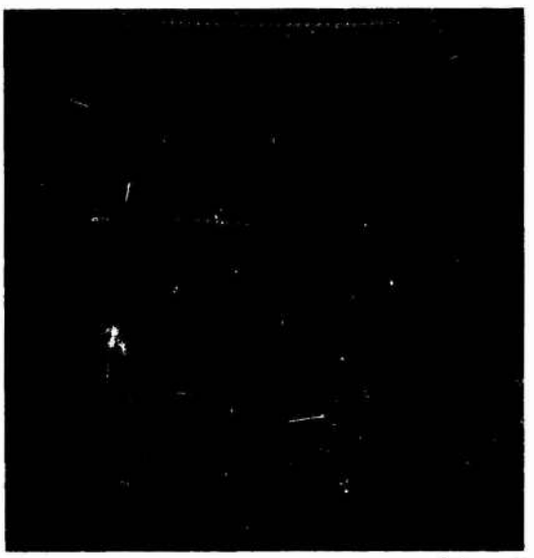
R. O. Stone

48. Steep wadi banks



Robert Perret[2]

51. The rocky surface of a hamada



Reference 18

52. Aerial view of a blowout in a vegetated sand area. A light-colored, U-shaped dune fringes the northern edge of the blowout

P. B. King, USGS[24]

ɔruptly

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

LANDFORMS - SURFACE CONDITIONS

DESCRIPTIONS AND PHOTOGRAPHS

PLATE 19B

Photo No.	CLASSIFICATION AND DESCRIPTION	Plan-Profile Units	Range at 1 | 2 Number 1
	III. MISCELLANEOUS (CONT.) **METEORIC**		
55	Meteorite craters: Steep-walled, saucer-shaped depressions produced by the impact and accompanying explosion of an object of extraterrestrial origin.	NA* NA	NA NA
	RESIDUAL		
56	Exfoliated boulders: A term applied to boulders whose surfaces have broken or peeled off as scales, lamellae, or concentric sheets.	This phenomenon is classed as a surf The boulders may be angular or roun inches to a few feet.	
57	Grus: The accumulation of countless discrete particles on the surface of granite sometimes extending to depths greater than 10 feet, which have formed from weathering of the various minerals forming the rock.	This phenomenon is classed as a surf Grus consists of angular fragments o	
58	Heat cracks: Irregular cracks which form in clayey soil by desiccation.	This phenomen is classed as a surfac These cracks may be from a fraction They enclose pologonal areas several above the central portion.	
	TECTONIC		
59	Basin ranges: Ranges of hills or mountains formed by faulted and tilted blocks of strata (separated by basins).	4 4, 4L, (5L, 5L//, 6L, 6L//)**	
60	Domal warps: Domal warps are roughly circular upwarps with beds dipping away from a central point. The surface expression is often that of centrally facing, concentric series of erosional scarps.	4, 4L 4, 4L	
61	Elongate domes: Elongate domes are elliptical upfolds, the beds dipping away from centrally located axes.	4, 4L 4, 4L	
62	Fault valleys: Fault valleys are relatively depressed fault blocks lying between faults with roughly parallel strikes.	1L, 7 1, 1L, 7	

LANDFORMS — SURFACE CONDITIONS: DES

Range at Yuma Range in Northwest African Desert Worldwide Range

Slope Occurrence Units

2 | 3 | 4 | 5 | 6

Number of Slopes Greater than 50% per 10 miles

5 20 100 200

Slope Units

1a | 1b | 2 | 3 | 4 | 5 | 6

Degrees

1 2 4 8 16 32 64

Relief Units

1 | 2 | 3 ← Relief Type I | Rel

4 | 5 | 6

Feet

10 50 100 400

To 3

To 3

s a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
or rounded fragments of igneous, sedimentary, or metamorphic rock. The boulders may range in diameter from 3

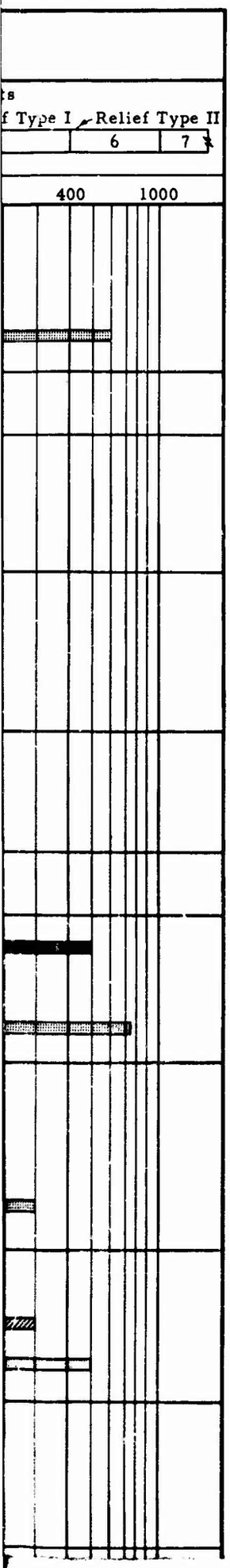
s a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
ments of weathered granite which may exhibit maximum diameter of several feet.

a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
fraction of an inch to several inches wide at the top and from a fraction of an inch to as much as 10 feet deep.
several inches to several feet across. The edges of the pologon warp upwards from 1 or 2 inches to several feet

To 5

To 5

: DESCRIPTIONS AND PHOTOGRAPHS



Jack Ammann Photogrammetric Engineers[22]

55. The famous Arizona meteor crater

C. R. Longwell[18]

56. A close-up of an exfoliated boulder showing the typical spalling action

Reference 18

59. Basin ranges in the center and background of the photograph separated by alluvial aprons

U. S. Army Map Service

60. An eroded domal warp forming a topographic basin

C. R. Longwell[15]

ated boulder
ng action

H. W. Turner, USGS[24]

57. Grus deposits resulting from weathering of igneous rock

La Belle Image[9]

58. Heat cracks

U. S. Army Map Service

forming a

Institut Géographique National, France[14]

61. A vertical photograph of a breached elongate dome with inward dendritic drainage

Dr. John S. Sheldon[16]

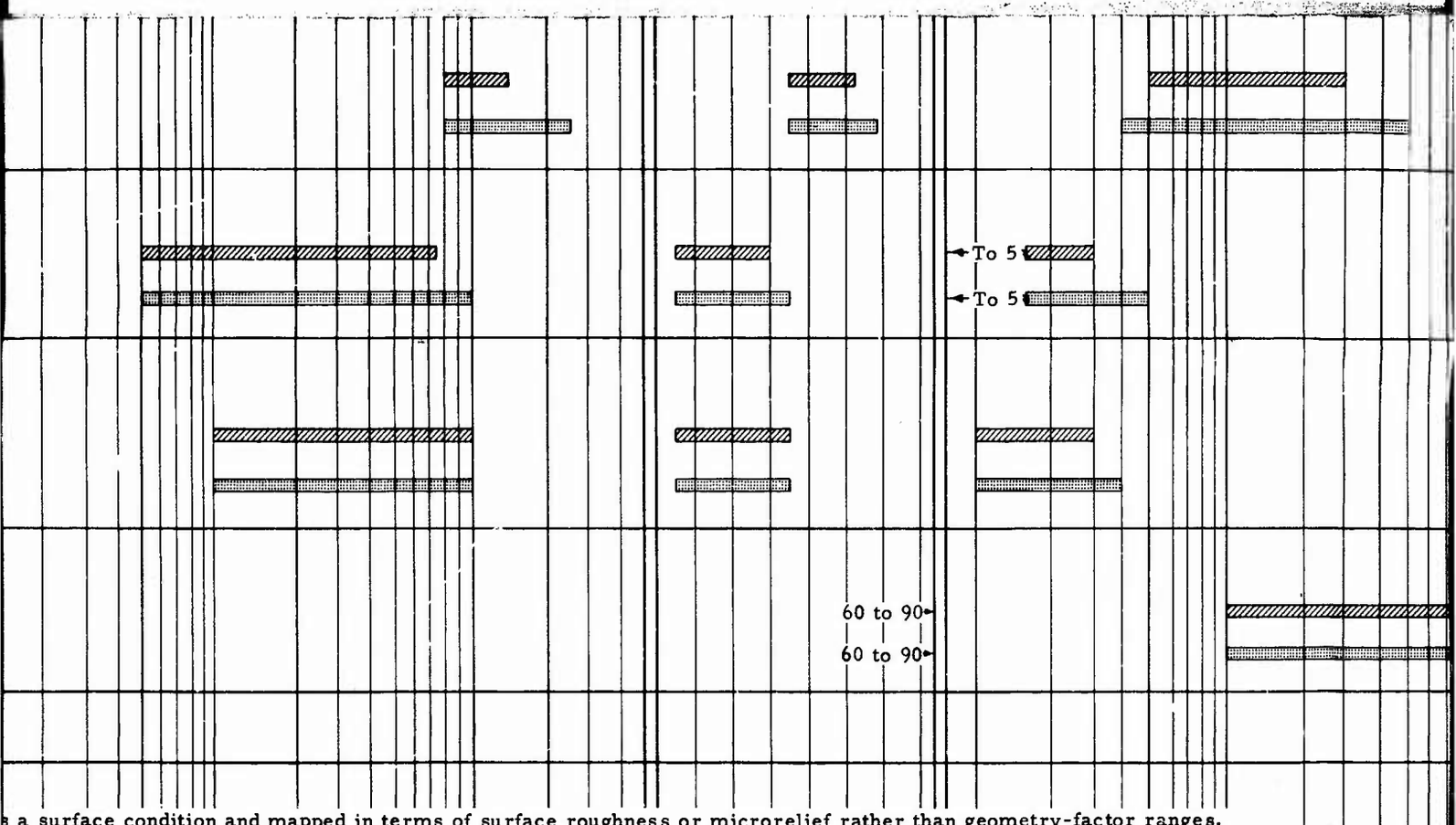
62. Areal view of Death Valley — a fault valley

61	**Elongate domes:** Elongate domes are elliptical upfolds, the beds dipping away from centrally located axes.	4, 4L 4, 4L			
62	**Fault valleys:** Fault valleys are relatively depressed fault blocks lying between faults with roughly parallel strikes.	1L, 7 1, 1L, 7			
63	**Intramontane valleys:** Intramontane valleys are narrow valleys or troughs with exterior drainage lying between mountains.	1 1, 1L			
64	**Scarps:** (For description see EROSIONAL, SURFACE WATER)	NA NA	NA NA		
	VOLCANIC				
65	**Broken lava flows:** Flat to undulating lava areas characterized by sharp-edged rocks and boulders.	This phenomenon is classed as a surf The surface of the flow is composed o			
66	**Cinder cones:** Cinder cones are conical hills formed by the accumulation of volcanic ash or clinkerlike material around a vent.	4, ⑥ 4, ⑥			
67	**Cinder fields:** Cinder fields are flat to undulating areas, often miles in extent, composed of volcanic ejecta that has mantled the preexisting landscape.	This phenomenon is classed as a surf Cinder fields have slopes which are o uncemented and have diameters rangi			
68	**Lava flows:** Lava flows are solidified stationary masses of igneous rock which issued from a volcanic cone or fissure.	This phenomenon is classed as a surf The slope of the surface of these flow surface may vary from several inche			
69	**Necks and plugs:** Necks and plugs are lava-filled conduits of an extinct volcano exposed by erosion.	4, 4// 4, 4//			

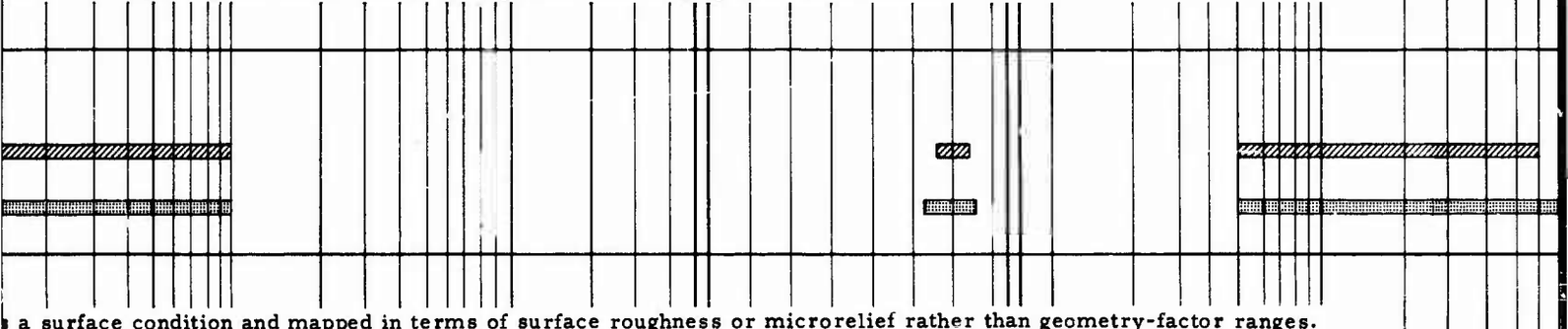
* Not applicable.

** Circled numbers indicate the plan and profile are both gross and restricted for worldwide conditions but only gross for

† Raised numbers refer to similarly numbered entries in the photographic bibliography at the end of volume I of this repo

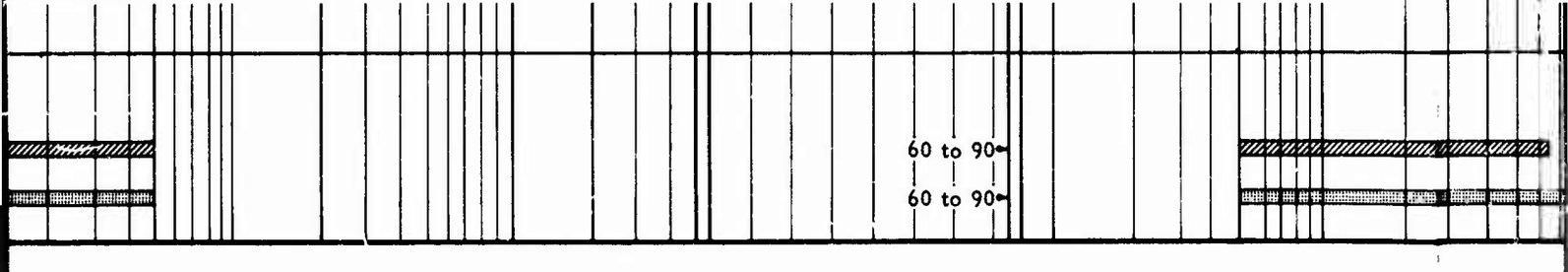


s a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
posed of large, angular blocks of lava having diameters ranging up to several feet.

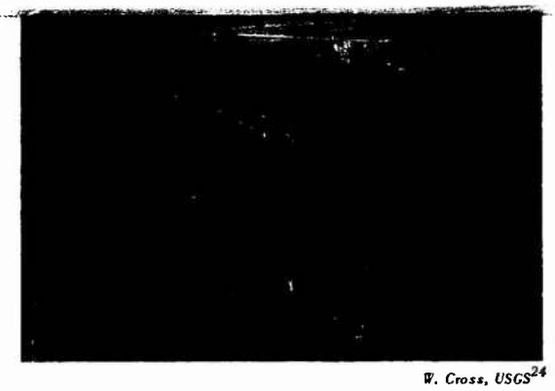


a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
h are determined to some extent by the underlying, preexisting landscape. The cinders themselves are angular and
s ranging between 4 and 32 mm.

a surface condition and mapped in terms of surface roughness or microrelief rather than geometry-factor ranges.
se flows varies from flat to gently undulating. Surface irregularities such as fragments of lava and fissures in the
l inches to 10 feet.

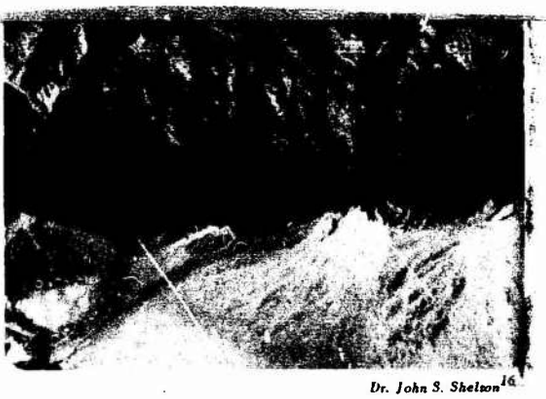


ss for Northwest Africa.
is report.



W. Cross, USGS[24]

63. An intramontane valley



Dr. John S. Shelton[16]

64. Aerial view of Black Mountain fault scarp furrowed by gorges south of Mormon, California

R. O. Stone

67. Cinder field at the northern edge of Death Valley, California

J. R. Balsey, USGS[24]

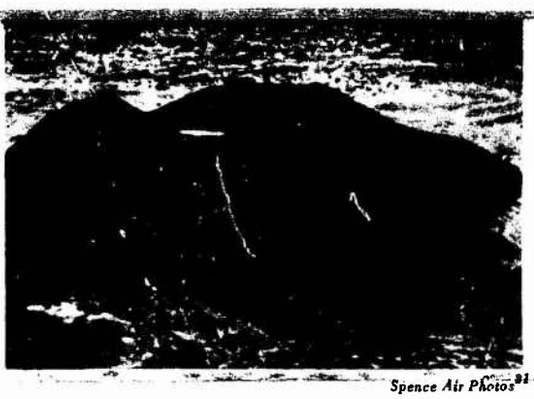
68. Lava flow with cinder cones in the lower left of the photograph

Dr. John S. Shelton[16]

ain fault scarp
of

R. A. Bagnold

65. A broken lava flow partially buried by windblown sand



Spence Air Photos[21]

66. Cinder cone

J. R. Balsey, USGS[24]

cones in the
ography

Photograph by O.F.A.L.A.C., observations P. Bordet[5]

69. Plugs towering over a volcanic region

ANALOGS OF YUMA TERRAIN
IN THE
NORTHWEST AFRICAN DESERT

LANDFORMS - SURFACE CONDITIONS

DESCRIPTIONS AND PHOTOGRAPHS

PLATE 19C

8

SUPPLEMENTARY

INFORMATION

Errata Sheet

ANALOGS OF YUMA TERRAIN IN THE NORTHWEST AFRICAN DESERT

Technical Report 3-630, Report 6
Volume II
June 1965

1. Plates 15, 15A, 19, 19A, 19B, 19C:

   Footnote on these plates reading

   "Raised numbers refer to similarly numbered entries in the photographic bibliography at the end of volume I of this report."

   should be changed to read

   "Raised numbers refer to entries in the Literature Cited following the main text of volume I of this report. Because of the addition of five entries at the beginning of the list of Literature Cited, each raised number in the credit lines under the photographs should be increased by 5, i.e. reference 19 should be reference 24, etc."

2. Plate 19C: The credit line under fig. 64 should be changed to read "Dr. John H. Maxson[21]"