REGIONALIZED VELOCITY MODELS IN CENTRAL ASIA

Bradley B. Woods, Chandan K. Saikia, Hong Kie Thio, and Gene Ichinose

URS Group Inc.

Sponsored by Defense Threat Reduction Agency

Contract No. DTRA 01-98-C-0151

ABSTRACT

We have developed regional velocity models to improve the location of small seismic events near the central Asian test sites. Specifically we have used seismograms recorded by International Monitoring System (IMS) stations, along with ISC and Calibration Event Bulletin (CEB) travel-time information, to generate velocity profiles extending radially from the Lop Nor Test Site; the best coverage is for the path to the northwest through the Semipalantinsk Test Site to, at the far end, the station BRVK. Most available crustal models developed for central Asia have a P_n velocity of 8.0 km/s; whereas the velocity profiles developed put P_n in the range of 8.3-8.4 km/s. Predicted travel times of P-waves traveling to the northwest of Lop Nor using these various models all yield negative residuals on the order of 2-6 seconds, suggesting these models are slower than the actual regional velocity structure. Hence, we examined a model for the Siberian Craton, the path over which these waves travel. The modified Leith model (Langston, 1998) has a Moho velocity of 8.3 km/s, closer to the velocities we found. Applying this model results in smaller travel-time residuals (0.5 sec. < *t*) rather than the 2-4 sec. residuals using the IASPI model, suggesting this model is more appropriate for the region. Similarly, a more appropriate model has been developed for paths to the NE and SE of Lop Nor, with a moho velocity of *8.26* km/s.

KEY WORDS: travel-time calibration, regional velocity model, location

OBJECTIVE

We have developed techniques to better locate small (mb< 4.5) seismic events, particularly for regions surrounding known nuclear test sites. Reliably locating and identifying these snaller events is of paramount concern to CTBT monitoring. Events of this size are usually only observed regionally ($\Delta <^{o}20$) as was the case of the August 16, 1997 Kara Sea event (Israelson *et al.*, 1997). Consequently we are concentrating on improving location capabilities for stations within 20^{o} of test sites in central Asia. To this end we have developed two regional velocity models for this area and compared them to the IASPI (Kennet and Engdahl, 1991) earth model. Where possible, velocity profiles were generated and analyzed to infer the P_n velocity of the regional crustal waveguide. Figure 1 is a map of the area of interest, denoting IMS and auxiliary stations, test sites and more recent (1988+) moderate-sized earthquakes in the region.

RESEARCH ACCOMPLISHED

After examining a number of existing crustal models for the region, both with respect to waveform modeling and travel time analysis, we found that these models, all of which had moho velocities of, or near, 8.0 km/s did not yield smaller travel-time residuals than the IASPI model. Travel time data used were from the ISC and the IMS's Calibration Bulletins; for some additional IMS station travels times were measured from records. Origin times and locations were taken from the the catalog of Engdahl *et al.* (1998) – afterwards referred to as the EHB catalog – when available. For the more recent Lop Nor explosions (1996) we used ISC locations, which were found to be compatible with the EHB solutions; the ISC origin times were modified by adding 1.7 seconds which, on average, is the difference between the EHB and ISC origin times for these nuclear explosions, reflecting the less accurate J-B model used in the ISC locations.

In order to arrive at a better crustal model we made a velocity profile to the N.W. of the Lop Nor test site

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **OCT 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**
4. TITLE AND SUBTITLE **Regionalized Velocity Models In Central Asia**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **URS Group Inc.,566 El Dorado St.,Pasadena,CA,91101**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Proceedings of the 23rd Seismic Research Review: Worldwide Monitoring of Nuclear Explosions held in Jackson Hole, WY on 2-5 of October, 2001. U.S. Government or Federal Rights.

14. ABSTRACT
See Report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

(LNTS) as this azimuth contains the four stations WMQ, MAK, KURK, and BRVK (the latter three of which are IMS stations), which provides the best source-station geometry for a velocity profile in the region. Figure 2 shows the constructed velocity profile; least-squares fitting yields a velocity of 8.40 ± 0.034 km/s. Table 1 provides the individual 2-station velocities, with "Profile Av." being the average of the separate individual 2-station path velocities; the bottom two entries are for paths respectively to the NE and SE of LNTS. The latter two paths only had available two stations per profile; hence they are considered less-robust velocity estimates; however, they also do suggest a difference in the moho velocity regimes.

The high P_n velocities found for the N.W. profile were found to be compatible to the modified Leith model for the Siberian Craton (Langston, 1995), which has a moho velocity of 8.35 km/s. The velocities for the NE and SE path are consistent with that found by Ni and Barrazangi for the Tien Shen (1983).

Given the P_n velocities we found, we decided to modify the IASPI model accordingly and redetermine travel times. For this we made two models, a further-modified Leith-Langston model (LL) for the NW path, and a more generalized central Asian model (modified IASPI) by incorporating a moho velocity of 8.26 km/s as well as a more appropriate crustal section into the IASPI model. Figure 3 compares these three models' *P*-wave velocities.

Table 2 compares the average travel-time residuals for the two modified models with the those from the IASPI model. The modified LL model yields smaller residuals for stations to the N.W., although residuals for stations at other azimuths tend to be as great or larger, suggesting that this model does better reflect the velocity structure to the N.W. of LNTS, into the Siberian Craton. The modified IASPI model does better, on average, than either the Siberian craton model or the IASPI model, suggesting that it, better reflects the average regional crustal waveguide and moho velocity than do either the IASPI or Siberian craton models.

CONCLUSIONS AND RECOMMENDATIONS

Our results suggest two regional models to be used for locating events centered about the LNTS. To the northwest of LNTS a crustal and upper-mantle structure reflecting the Siberian craton (moho velocity = 8.35), put atop the IASPI model, provides the best improvement in travel-time residuals; while for the other azimuths a regionalized crustal waveguide model with a moho velocity of 8.26 yields smaller residuals on average than either the IASPI or Siberian craton model. Thus it appears that the region can be modeled by two regional velocity models: the modified LL model for the N.W. azimuth, while the modified central-Asian IASPI model works for other azimuths. Similar analysis should be done for the path due west of LNTS, towards AAK. Results at the conference will include analysis of relocated earthquakes' travel times; these events are shown in Figure 1. These finalized regional models should then be tested on larger data sets to verify their improved locating ability for events in central Asia.

REFERENCES

Engdahl, R. E., R. van der Hilst, and R. Buland (1998), Global teleseismic earthquake relocation with improved travel times and procedures for Depth Determination, *Bull. Seism. Soc. Am., 88, 772-743.*

Israelsson, H., M. D. Fisk, X. Yang, and R. G. North (1997), The August 16, 1997 event in the Kara Sea, *CMR Technical Report*, CMR-97/38, Alexandria, VA.

Kennett, B. L. N. and E. R. Engdahl (1991). Travel times for global earthquake location and phase identification, *Geophys. J. Int.*, 105, pp. 429-465.

Langston, C. A. (1995), Anatomy of regional phases and source characterization of the Soviet Joint Verification Experiment, *Bull. Seism. Soc. Am.*, 1416-1431.

Ni, J. and M. Barazangi (1983), High-frequency seismic wave propagation beneath the Indian Shield, Himalayan Arc, Tibetan Plateau and surrounding regions: high uppermost mantle velocities and efficient S_n propagation beneath Tibet, *Geophys. J . R. astr. Soc.*, 72, 665-689.

Table 1. Apparent Pn Velocities

Path	Velocity	σ	Num.
KURK-BRVK	8.34 km/s	0.099	6
MAK-KURK	8.45 km/s	0.025	6
WMQ-MAK	8.43 km/s	0.071	4
Profile Av.	8.39 km/s	0.099	23
WMQ-TLY	8.29 km/s	0.065	3
GTA-LZH	8.26 km.s	0.033	8

Table 2. Travel-time Residuals

Sta	IASPI	Mod. LL	Mod. IASPI
WMQ	3.6 ± 0.72	0.3 ± 0.28	0.6 ± 0.42
MAKZ	-0.8 ± 0.44	1.0 ± 0.33	-0.1 ± 0.23
AAK	-2.6 ± 1.18	-0.3 ± 0.30	-2.0 ± 0.58
KURK	-2.4 ± 0.20	0.1 ± 0.15	-1.8 ± 0.19
LSA	2.9 ± 0.68	5.9 ± 0.70	3.9 ± 0.73
LZH	-0.7 ± 0.51	2.4 ± 0.58	0.3 ± 0.53
TLY	1.4 ± 0.13	4.5 ± 0.19	2.1 ± 0.16
ULN	-1.2 ± 0.09	2.8 ± 0.14	0.4 ± 0.10
NIL	-3.4 ± 0.47	0.3 ± 0.35	-2.2 ± 0.41
BRVK	-6.8 ± 0.16	-4.0 ± 0.12	-6.9 ± 0.18

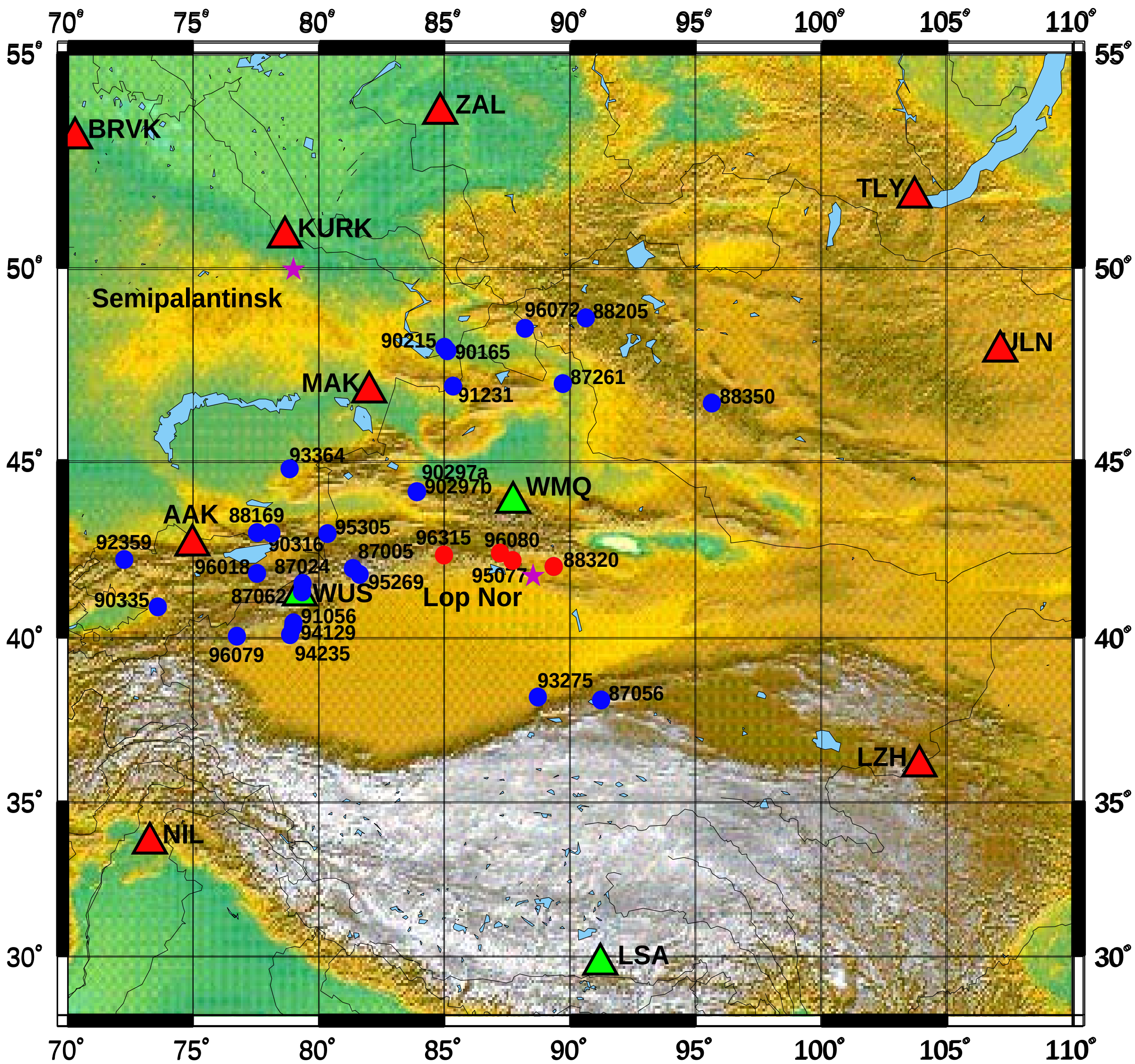

Figure 1. Map of study area showing IMS stations as well as the two auxiliary stations WMQ and LSA (all triangles); test sites are denote by stars, and moderate-sized recent earthquakes by small circles.

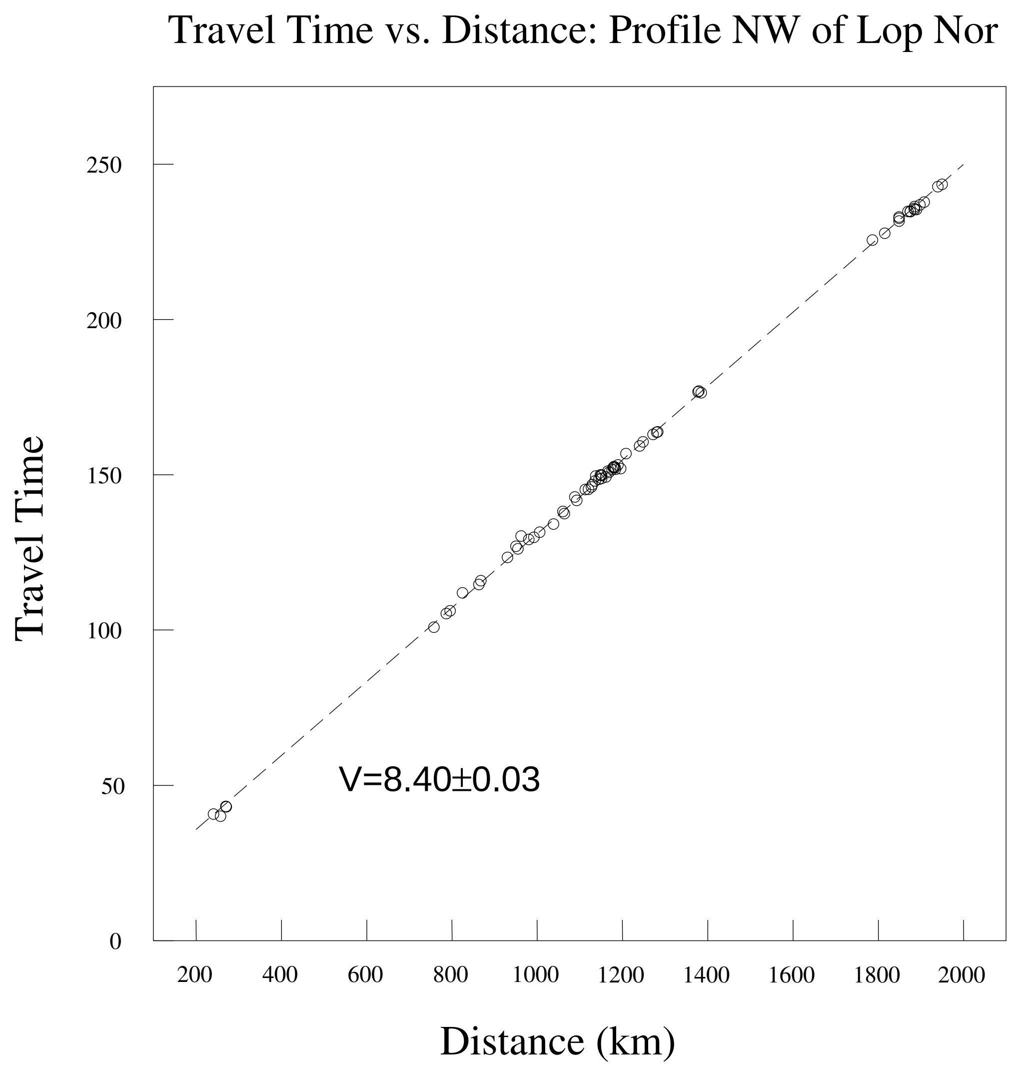

Figure 2. Velocity profile for the azimuth to the N.W. of Lop Nor. The dashed line represents the least-squared derived velocity of *8.403* ± *0.034* km/s.

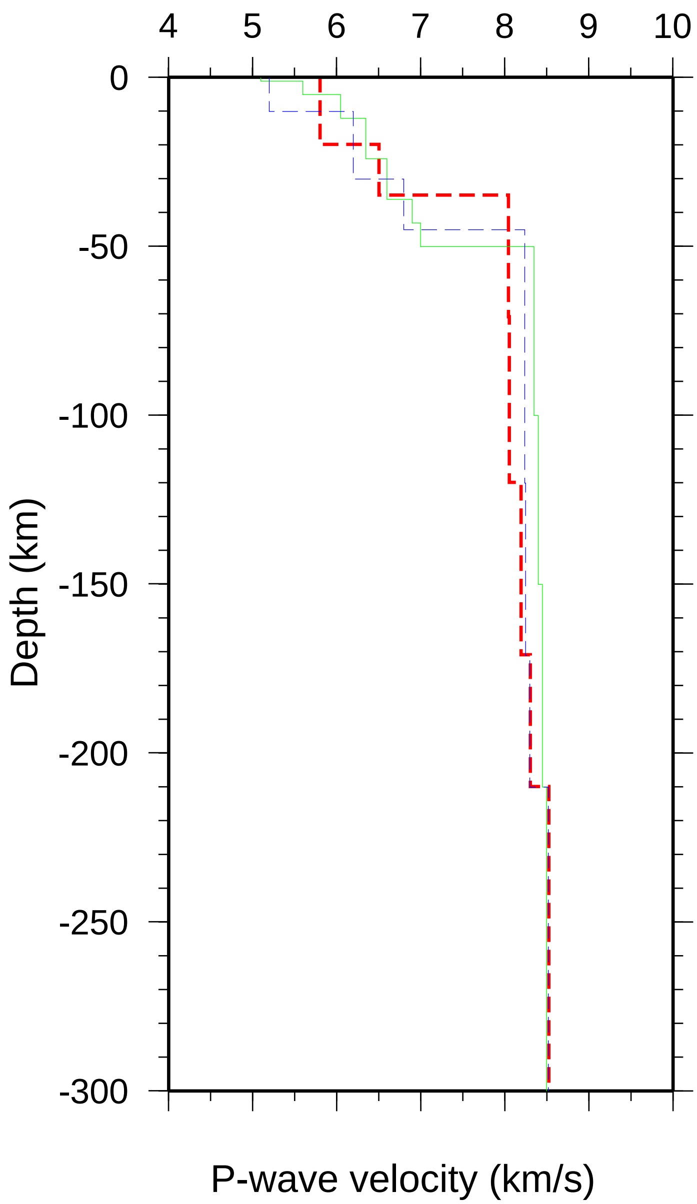

Figure 3. Comparison of velocity models: IASPI (long dash), modified Leith-Langston model (solid line), and the modified IASPI model (short dash).