DEEP SEISMIC SOUNDING DATA SETS FOR SEISMIC CALIBRATION OF NORTHERN EURASIA

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ABSTRACT

Over the next three years, in cooperation with the Centre of Regional Geophysical and Geological Research (GEON), Moscow, Russia, the University of Wyoming will obtain, preprocess, and transfer to the Incorporated Research Institutions in Seismology (IRIS) a series of unique long-range Deep Seismic Sounding (DSS) profiles. These datasets will include nine major DSS projects using 22 Peaceful Nuclear Explosions (PNEs), several hundred of chemical explosions, and recordings of natural seismicity in Northern Eurasia. This project is jointly supported by the Defense Threat Reduction Agency (DTRA01-01-C-0081; 75% of funding) and the National Science Foundation (EAR-0092744; 25%). The data from project QUARTZ have already been transferred to IRIS.

The profiles were recorded between the early 1970's and late 1980's using ~400 three-component analog instruments, with recordings of 2-4 PNEs and several dozens of chemical explosions (per profile) at the same locations. Long listening times (up to ~600 sec after the first arrivals) allowed recording of the secondary phases (*S*, *Lg, Pg, Rg*) that are critical for nuclear explosion monitoring. The energies of the PNE sources (magnitudes >5) were sufficient for reliable recordings beyond 3000 km; including several reflections from the core-mantle boundary.

DSS PNE data have been widely recognized as an unparalleled source of seismic information about the detailed structure of the upper mantle down to 400- to 800-km depth and even to the Earth's core. DSS data present an unparalleled source of such information that is practically impossible to obtain by other means. The core PNE data sets of the DSS program cover an intermediate distance range between 0 – 3200 km bridging the gap between the conventional controlled source, earthquake, and nuclear–explosion-monitoring seismology. The dense, linear systems of PNEs and chemical explosions allow obtaining unusually detailed models of the crust and uppermost mantle over 4000-km long geotraverses. These datasets provide virtually the only dense three-component recordings of regional phases in aseismic regions of Northern Eurasia.

Numerous publications (primarily by GEON, Russian Academy of Sciences, the University of Wyoming, Potsdam/Karlsruhe, and Copenhagen groups) have presented velocity, reflectivity, attenuation, scattering, and receiver function models inspired by these profiles. When made broadly accessible for nuclear test monitoring research, the datasets will boost research on seismic calibration of the region and on transportable seismic discriminants in Asia. From a broader scientific perspective, the digitized DSS recordings and models of the upper mantle could also provide ideal reference and calibration data sets for the detailed structure of the upper mantle targeted by the initiative of USArray.

OBJECTIVE

Over the past three decades, Russian scientists acquired a network of dense, linear, long-range, three-component Deep Seismic Sounding (DSS) profiles using conventional and Peaceful Nuclear Explosions (PNEs) over a large territory of Northern Eurasia. These historic data provide unique opportunities to calibrate existing seismic nuclear discrimination techniques by studying regional wave propagation through complex lithospheric structures.

The objective of this research is to complete digitization, verify, edit and make broadly available through IRIS data repository a significant part of the unique collection of DSS PNE datasets currently stored at Centre GEON. The data processed and transferred to IRIS over four years of this work will include 22 PNEs recorded by nine major seismic projects (Figure 1). For the first time, this effort will deliver to the broad seismological and seismic monitoring community a set of unparalleled recordings of a large number of nuclear explosions recorded across a variety of propagation paths to the distances of ~3000 km.

RESEARCH ACCOMPLISHED

DSS PNE data have been widely recognized as an unparalleled source of seismic information about the detailed structure of the upper mantle down to 400- to 800-km depth and even to the Earth's core. DSS data present an unparalleled source of such information that is practically impossible to obtain by other means. The core PNE data sets of the DSS program cover an intermediate distance range between 0 – 3200 km bridging the gap between the

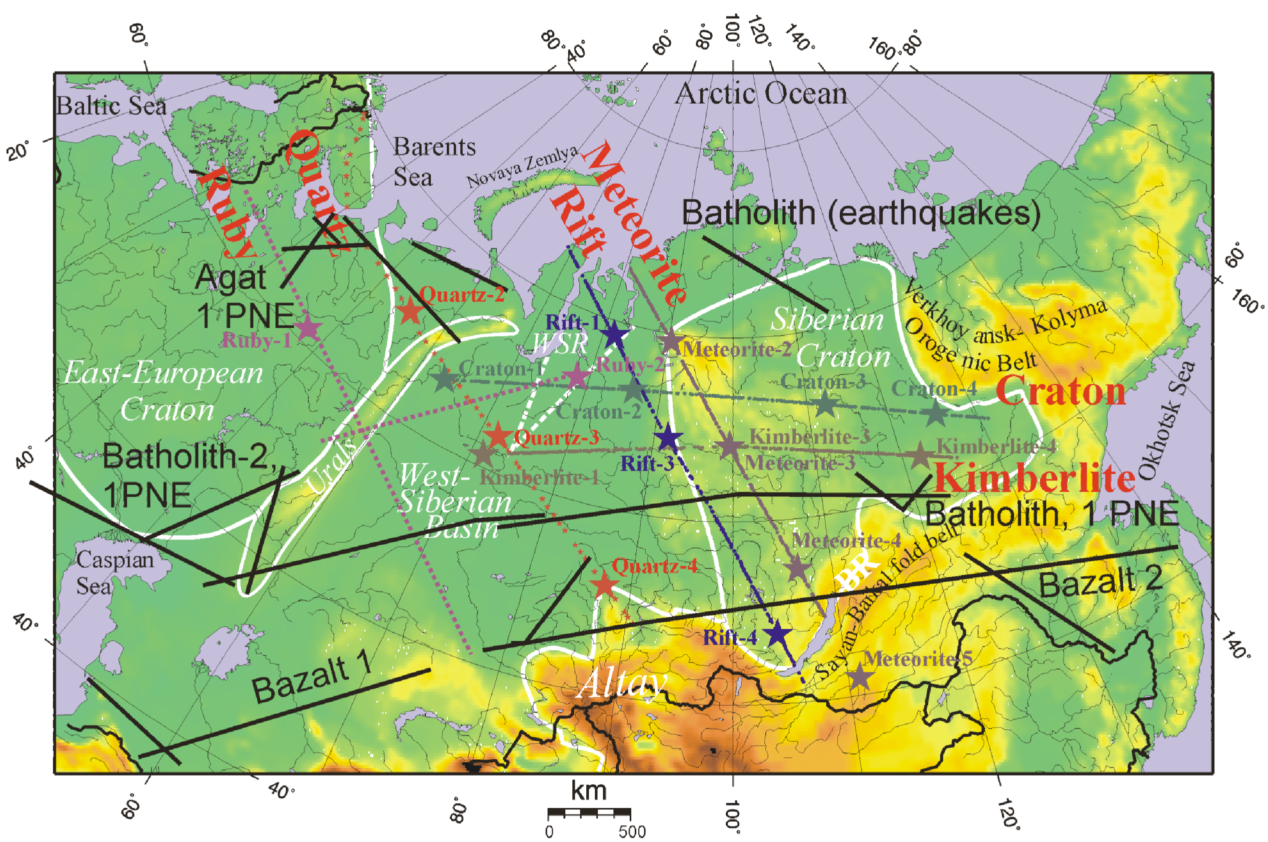

Figure 1 Nine DSS PNE projects to be delivered to IRIS as a result of this project. The data from profile QUARTZ and the PNEs from profile CRATON have already been delivered to IRIS. Colored lines and stars indicate the profiles and PNEs that have been digitized previously, black lines are the profiles to be digitized in this work. The coordinates and other parameters of the PNEs used in these profiles were reported by Sultanov et al. (1999). Major tectonic units are indicated. Note the extent of systematic, continuous profiling, with PNEs detonated at the nodes of a 2-D recording grid. Note that the profiles cover a vast asiesmic area that would be difficult to calibrate by other means.

conventional controlled source, earthquake, and nuclear explosion monitoring seismology. The dense, linear systems of PNEs and chemical explosions allow obtaining unusually detailed models of the crust and uppermost mantle over 4000-km long geotraverses. These datasets provide virtually the only dense three-component recordings of regional phases in aseismic regions of Northern Eurasia.

The data are being digitized at Centre GEON, Moscow, and preprocessed and edited at the University of Wyoming. PNE yields were between 7-23 kton providing reliable seismic recording throughout the full recording ranges (Figure 1). Continuous and often reversed PNE recordings allow observations of seismic phases diving to depths of ~800 km (e.g., Egorkin et al, 1987; Ryaboy, 1989; Kozlovsky, 1990; Morozova et al., 1999). On a typical PNE profile, 3-4 nuclear explosions were recorded at up to 400 of three-component seismograph stations with nominal spacing of 10 to 15 km. About 50-80 chemical explosions (typically, each 3000 – 5000 kg) per profile were also recorded to enable interpretation of crustal and uppermost mantle structures. The locations, depths, yields, and times of the PNEs, and characterizations of the source conditions were recently reported by Sultanov et al., (1999).

DSS profiles cross a variety of contrasting tectonic structures in Northern Eurasia and their studies have resulted in detailed images of the crust and uppermost mantle (Yegorkin, 1992). Some of the recent interpretations were performed by Egorkin and Mikhaltsev (1990), Mechie et al. (1993, 1997), Cipar et al. (1993), Priestley et al., (1994), Ryberg et. al. (1995, 1996), Schueller et al., (1997), Lorenz et al. (1997), Morozov et al. (1998a), and Morozova et al. (1999). The interpretations of the profile QUARTZ (Figure 2) by the University of Wyoming utilized the full spectrum of seismic data, including refractions and reflections from all 51 explosions of the dataset, lithospheric multiples, crustal-guided phases, seismic attenuation (Morozov et al., 1998b), coda amplitude decay (Morozov and

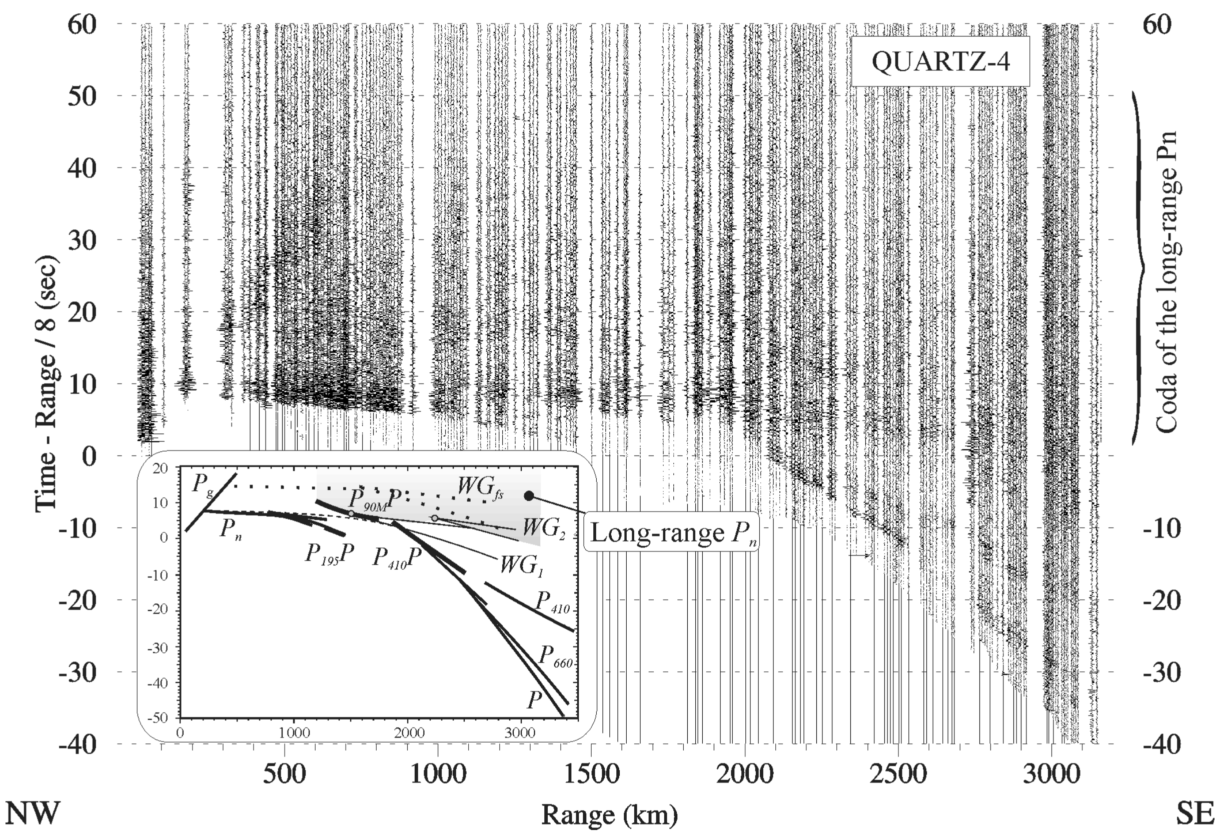

Figure 2. Vertical component record from PNE QUARTZ-4 (Figure 1). Inset shows a sketch of seismic phases identified in the wavefield. Note the free-surface and Moho *P*-wave multiples (*PP*, or whispering-gallery modes) labeled *WGfs* and *WG*, respectively. These phases were interpreted as caused by strong scattering within the uppermost mantle (Ryberg et al., 1995); however, in another interpretation, they may be due to a strong velocity gradient and mantle layering beneath the East European platform and the southern part of the West Siberian Basin (Morozov, 2001). Both of these inferences might have significant implications for nuclear test monitoring along the critical NW-SE paths across the East European Platform.

Smithson, 2000), receiver functions (Morozov et al, in press), and empirical travel-time regionalization (Morozov et al., in final preparation). Using travel-time, amplitude, and attenuation data, this study resulted in unusually well constrained images of crustal and mantle heterogeneity (Schueller et al., 1997; Morozov et al. 1998a, 1998b; Morozova et al., 1999). PNE data served as a basis for a new class of stochastic models of the uppermost mantle (e.g., Ryberg et al., 1995; Enderle et al., 1997), which, however, also resulted in a significant controversy (Morozov et al., 1998a; Morozov, 2001) and are being actively debated at present. The datasets contain spectacular and unusually continuous, three-component recordings of regional phases (Figure 3) still hold great potential for nuclear explosion monitoring research (for more detail, see our reports to several previous SRR symposia).

According to the schedule, to date, we have delivered to IRIS digitized seismic data from profile QUARTZ and PNE records from profile CRATON (Figure 1). The schedule for further planned data deliveries is given in the following table.

#	Data set (Figure 1)	Edited and reduced data delivered to IRIS DMS (months after November 2001)
1	QUARTZ	1
2	CRATON	9
3	KIMBERLITE	12
4	RIFT	18
5	METEORITE	24
6	RUBY	30
7	BATHOLITH-1,2	36
8	BAZALT-1,2	42
9	AGATE (5 profiles)	48

CONCLUSIONS AND RECOMMENDATIONS

Preliminary examination of the newly obtained Russian PNE records from the Siberian DSS PNE profiles demonstrates that the data provide valuable information for the analysis of the propagation of L_g and other phases for their use in nuclear explosion monitoring and calibration studies. When made broadly accessible for nuclear explosion monitoring research, the datasets will boost research on seismic calibration of the region and on transportable seismic discriminants in Asia. Greater availability of the unique PNE recordings would foster current research on several DoD-sponsored projects and facilitate extension of such research in the future. Also, from a broader scientific perspective, the digitized DSS recordings and models of the upper mantle could also provide ideal reference and calibration data sets for the detailed structure of the upper mantle targeted by the initiative of USArray.

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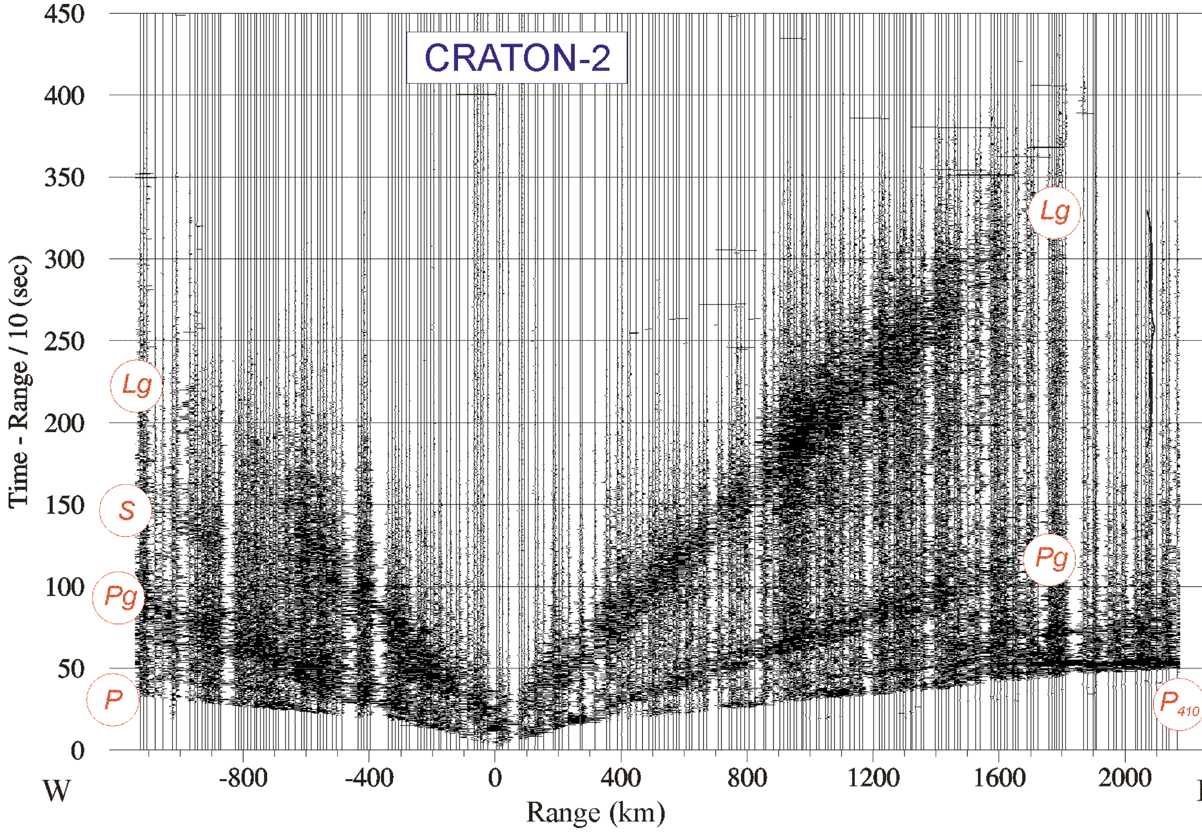

Figure 3. Vertical-component record from PNE CRATON-2 (Figure 1). Note the continuity of arrivals extending to the transition zone discontinuities. Also note the strong *Lg* and *Pg* propagating to the ranges exceeding 1600 – 1700 km, and the differences between the character of *S* wave and *Lg* in two directions from the PNE. *Lg* is very strong east of the shot point (under the Siberian Craton) whereas the mantle *S*-wave propagates efficiently to the west, under the West Siberian basin (Figure 1).