DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

Geology of NRDC Seismic Station Sites in Eastern Kazakhstan, USSR

by

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Open-File Report 87 - 597

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1987

SUMMARY

The three seismic stations that were installed around the Soviet nuclear testing ground in eastern Kazakhstan in 1986 by the Natural Resources Defense Council, all are located on granitic intrusions that are remarkably similar to Degelen mountain, in the central testing area of the nuclear testing ground. These intrusions all consist of an alaskite granite core of Permo-Triassic age, complexly intruded into a number of earlier granitic to basic igneous phases, including basalt, rhyolite and syenite, surrounded by complexly deformed, late Paleozoic sedimentary rocks. The mapped outcrops of the granitic bodies are marked by prominent negative gravity anomalies, attesting to the low density of alaskite relative to the surrounding country rock. Seismic refraction data indicate a thick crust (~50 km) and high seismic Pn wave velocities (8.0 - 8.3 km/sec) beneath the Karkaralinsk and Bayanaul intrusions, and somewhat thinner crust and lower Pn velocities beneath the Del'begetey intrusion (Karasu site). Because of their proximity and marked similarity to Degelen mountain, seismic data from these initial sites may be useful for seismic reciprocity studies when applied to the study of seismic sources from Degelen.

INTRODUCTION

The recent installation of three seismic stations by the Natural Resources Defense Council (NRDC) around the Soviet Nuclear Testing Ground in eastern Kazakhstan (*1, 2*) has produced the need for detailed study of local geologic variability in that region, both for the purpose of evaluating differences in seismic wave propagation between the three sites and for evaluating possible reciprocity relationships (*3*) for seismic waves recorded at these sites that have emanated from the U. S. Nevada or other test sites.

The three NRDC seismic stations, "Karkaralinsk", "Bayanaul", and "Karasu" (named after nearby towns), are all located on granitic intrusions of late Paleozoic/early Mesozoic age (Fig. 1). Station names are, except for Karasu, consistent with the geologic nomenclature for the intrusions upon which they are located (the Karasu site is located on the Del'begetey intrusion). These intrusions are located within the Kazakh fold system (*4*), a multiply- deformed belt of folded and faulted, mostly Paleozoic rocks that was marked by extensive igneous activity during the late stages of the Hercynian orogeny, in Permo-Triassic time. Each of the granite bodies was intruded into earlier igneous phases, surrounded by complexly-deformed sedimentary rocks of mid-late Paleozoic age (*5*).

Recent tectonic activity in the region includes regional crustal uplift and thickening, widespread faulting and low-level seismicity (*6*). These tectonics have resulted in moderate variations in crustal thickness, heat flow and upper mantle seismic velocities across the region (*7*; see Fig. 2). The Karkaralinsk and Bayanaul stations rest on what is estimated to be some of the thickest crust in the region (~50 km), atop a broad crustal uplift with low heat flow, whereas the Karasu station is located atop somewhat thinner crust and higher heat flow (see Table 1).

Compositionally, the Karkaralinsk, Bayanaul and Del'begetey intrusions are all dominated by alaskite, an alkalai feldspar granite of slightly lower density and seismic velocity than normal granite (*8*). This is the same rock type comprising the central portion of Degelen mountain (*9*), which appears to comprise most of the central testing area of the principal Soviet nuclear testing ground near Semipalatinsk (*10*). While the U. S. has some limited experience with underground nuclear tests in granitic rocks, these tests have been in granodiorite (e.g., in the Climax stock, U.S.

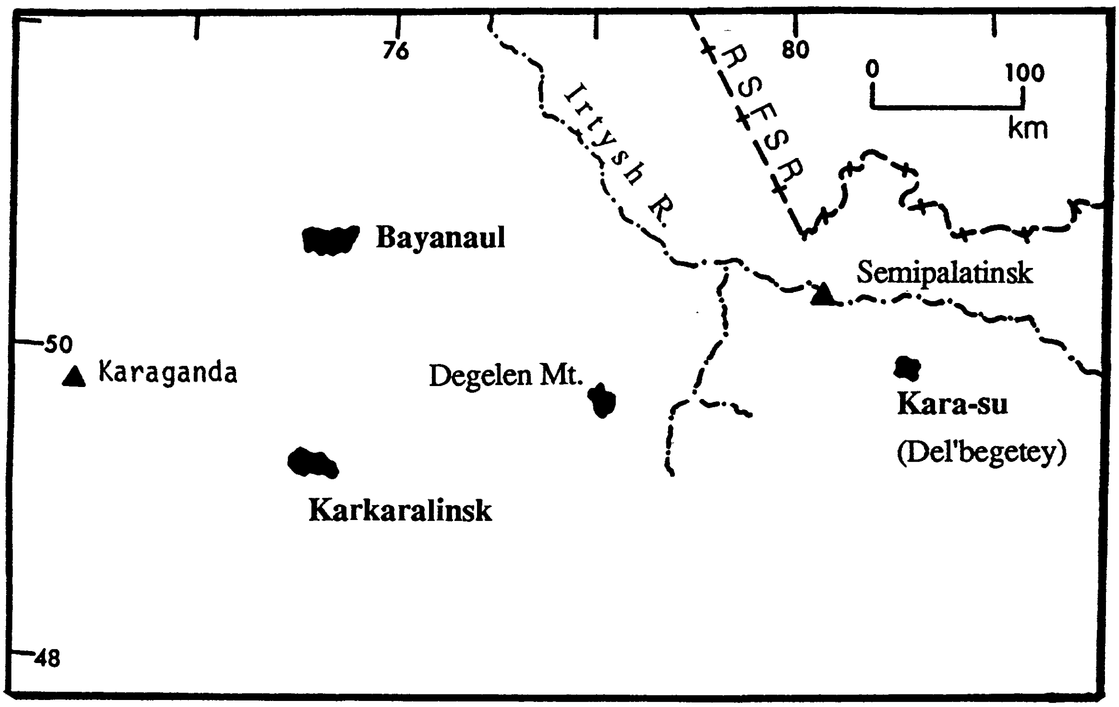

Fig. 1. Sketch map of eastern Kazakhstan, showing the locations of the granitic intrusions on which the NRDC seismic stations are situated. Also shown for reference is the location of Degelen mountain, in the Soviet nuclear testing ground.

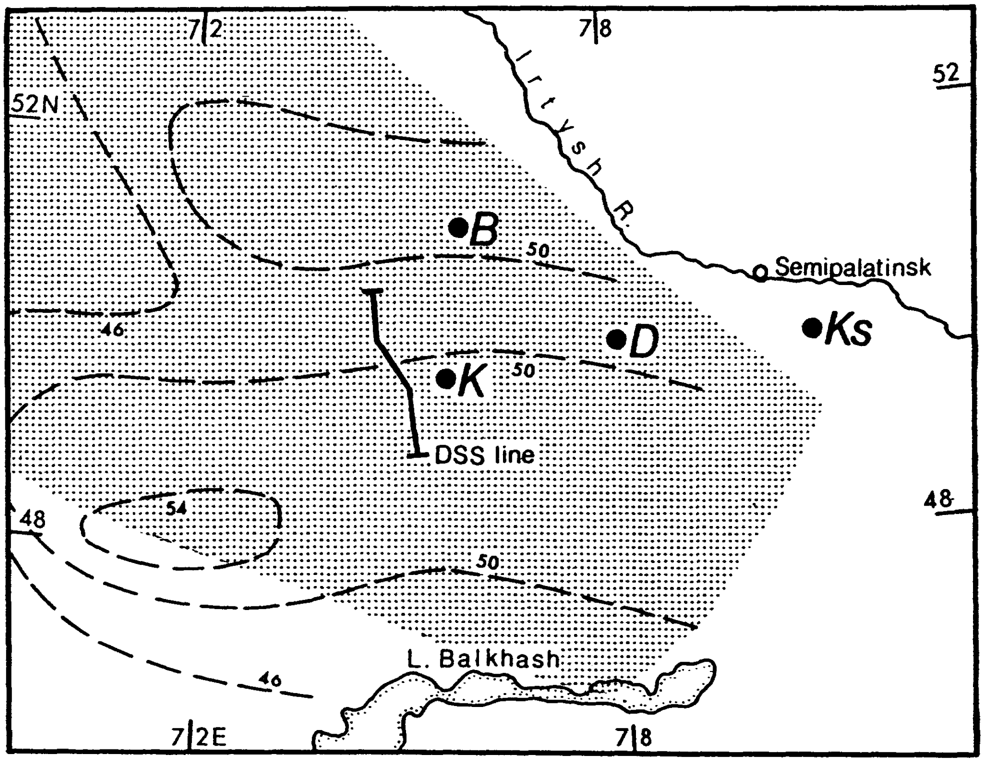

Fig. 2. Contours of crustal thickness (thin lines, in km), with shading indicating upper mantle seismic Pn velocities as follows: shaded area = 8.3 - 8.5 km/sec; neutral = 8.0 - 8.2 km/sec (after Antonenko, 1985, ref. 7). Segmented line indicates the location of the Karkaralinsk seismic refraction (DSS) profile. Seismic stations as follows: B = Bayanaul; K = Karkaralinsk; Ks = Karkaralinsk. Degelen mountain is marked "D". Data are incomplete to the east of Semipalatinsk.

TABLE 1

station name	**depth to Moho** (km)	**Pn velocity** (km/sec)	**Heat flow** (10^{-2} watts/m^2)
Bayanaul	50	8.3 - 8.5	3 - 4
Karkaralinsk	50	8.3 - 8.5	~4
Karasu	~ 40. (?)	8.0 - 8.2	~ 7 - 8. (?)
(Degelen)	48 - 50	8.3 - 8.5	3 - 4

Table 1. Estimates of crustal thickness, upper mantle seismic velocity and regional surface heat flow beneath the NRDC seismic station sites and for the area of Degelen mountain on the nuclear testing ground (7). For the Karasu site, depth to Moho is based on interpreted gravity data, and heat flow values are estimated from extrapolation of trends just to the west of the site. These values should be regarded as relatively less precise than other figures in the table.

Nevada test site). Densities for Soviet alaskites, including average densities for the Karkaralinsk, Bayanaul and Del'begetey intrusions, are compared in Fig. 3 with average densities for the granodiorite of the Climax stock (*11*) and the granite of the Hoggar massif, French Algerian test site (*12*).

The geological and geophysical data that are available for the three NRDC sites is generally better than that available for Degelen mountain itself, but they vary in type and detail for each of the sites. For instance, cross-sectional gravity anomalies have been published for a profile across the Del'begetey intrusion, while the Karkaralinsk intrusion is located near a crustal deep seismic refraction (DSS) profile. By compiling the various pieces of data from each location, one can build a rather satisfying picture of the general characteristics of these granitic intrusions. However, subtle differences between individual intrusions may not be resolved by the available data. The following are brief descriptions of the geology and crustal structure of each site (*13*), presented here for their utility both in interpreting seismic data and in evaluating them as an analog to Degelen.

INDIVIDUAL SITE SUMMARIES

Karkaralinsk - The seismic station that was sited near the town of Karkaralinsk is located on the Karkaralinsk granitic intrusion, of late Paleozoic/early Mesozoic age (*14*). It is composed predominantly of alaskite, with lesser areas of various granitic porphyrys and diorites. The alaskite is composed of an average of 45% quartz, 40% microcline, 13% albite and orthoclase, and 2% biotite and accessory minerals. Density determinations on a set of 2070 samples of Karkaralinsk alaskite had a mean density of 2.54 g/cc (see Fig. 3), with a dispersion of 0.03 and a range of 2.42 - 2.68 g/cc (*15*). These values are typical for alaskites from eastern Kazakhstan, and indicate seismic p-wave velocities of less than 5.5 km/sec beneath the station (*16*).

The Karkaralinsk intrusion outcrops over an area of about 15 x 30 km. However, like Degelen (*9*), geophysical surveys (*17*) indicate that the Karkaralinsk granite is laccolithic (mushroom-shaped) at depth, narrowing to a central stock about 10 km in diameter at at depth of 10 km (Fig. 4). A seismic refraction (DSS) profile was undertaken by the Soviets in the late 1960's along the Zharli river, 20 km west of Karkaralinsk (see Fig. 1). An interpretation of the results of this experiment in terms of an average seismic velocity structure for the crust and upper mantle near Karkaralinsk is shown in Fig. 5 (adapted from sources listed in *18*).

Bayanaul - The seismic station that was sited near the town of Bayanaul is located on Akbet mountain, atop the Bayanaul granitic alaskite intrusion (*20*). The alaskite is composed of 35-40% quartz, 60% microcline and minor plagioclaise and biotite. These values compare well with the Degelen alaskite, which is reported as 30-40% quartz, 50-60% microperthite, 7-15% albite and orthoclaise, and 0-2% biotite and accessories. Density determinations on a set of 97 samples of the Bayanaul granite (*15*) had a mean density of 2.53 g/cc and a range of 2.48 - 2.59.

Karasu - The seismic station that was sited near the village of Maliy Karasu is located atop the Del'begetey intrusion, which is variously described as alaskite or leucocratic biotite granite (*20*). Density determination on a set of 27 samples of Del'begetey granite (*15*) had a mean density of 2.56 g/cc, and a range of 2.40 - 2.67 g/cc (*9*). A gravity survey of the intrusion (Fig. 6) suggests that the alaskite granites are considerably less dense than the the surrounding country rock. This is apparently a common characteristic of granitic intrusions in this portion of Kazakhstan, and has been proposed as the explanation for the apparent uplift of these intrusions relative to the surrounding rocks (*21*).

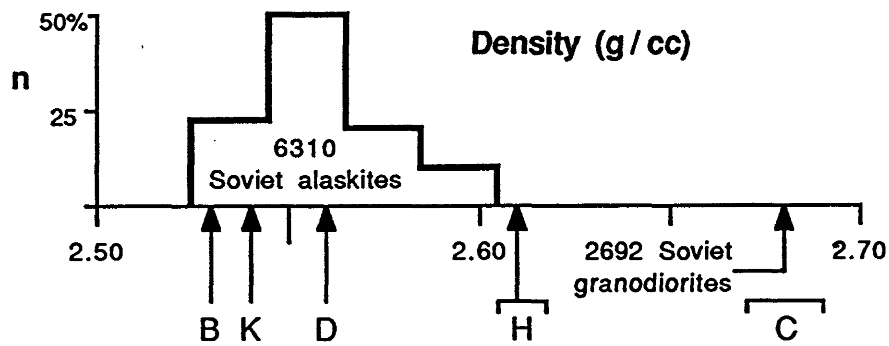

Fig. 3. Comparison of the distribution of alaskite densities (bar graph) from 6023 samples of alaskite taken from the Soviet Union (*8*) with mean densities reported for the Karkaralinsk (K), Bayanaul (B) and Del'begetey (D) intrusions. Also shown for comparison are the mean density and range for the Hoggar granite (French Algerian test site) and for the granodiorite of the Climax stock (U.S. Nevada test site).

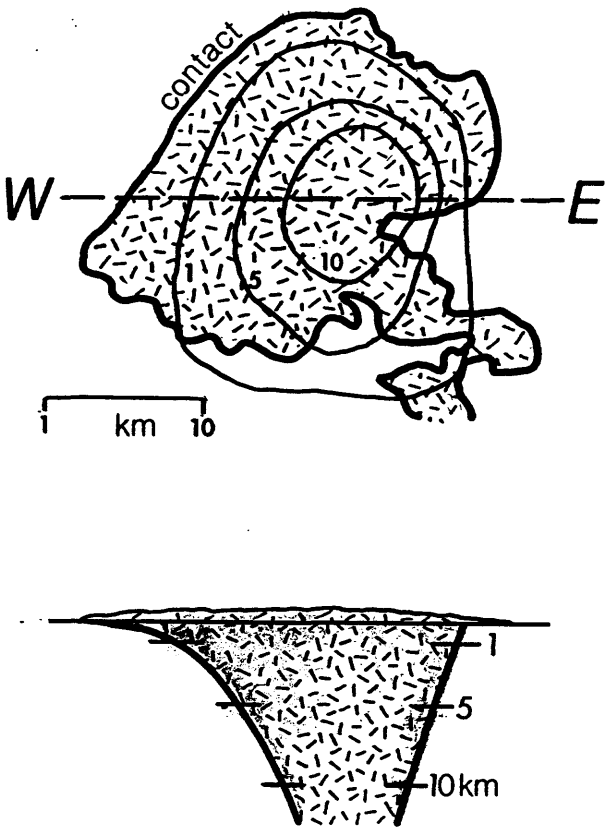

Fig. 4. Plan view (upper) and cross-section (lower), showing the form of the granitic stock of the Karkaralinsk intrusion, based on interpreted geophysical data (*14*). The Degelen intrusion is also thought to be similarly mushroom-shaped (*9*).

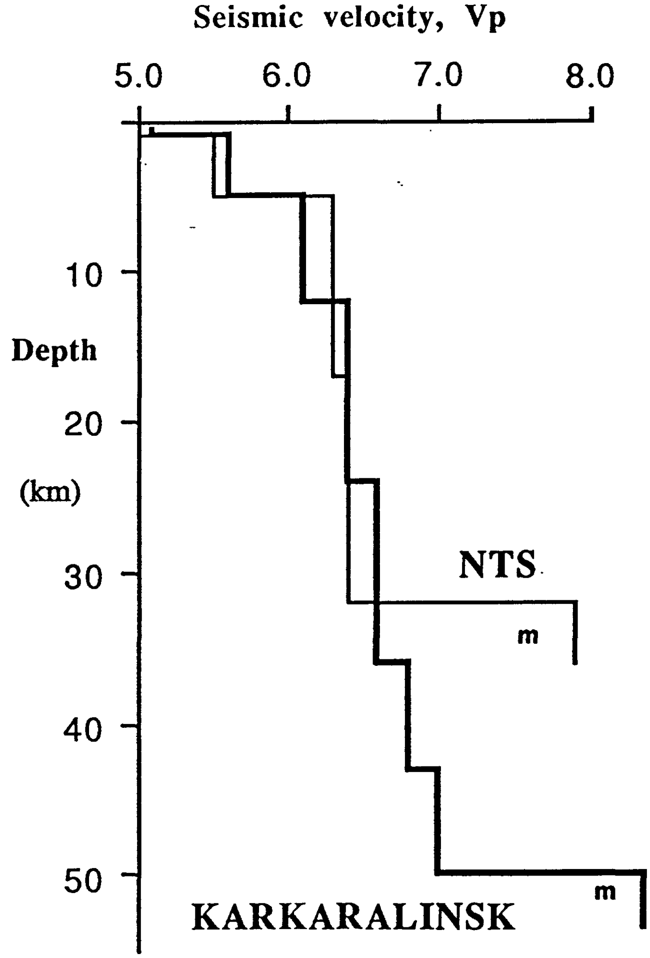

Fig. 5. P-wave layer velocity structure for the crust at Karkaralinsk, based on seismic refraction data (*15*). A model for the p-wave layer velocity structure at the U. S. Nevada test site (Rainier Mesa) is shown for comparison (17).

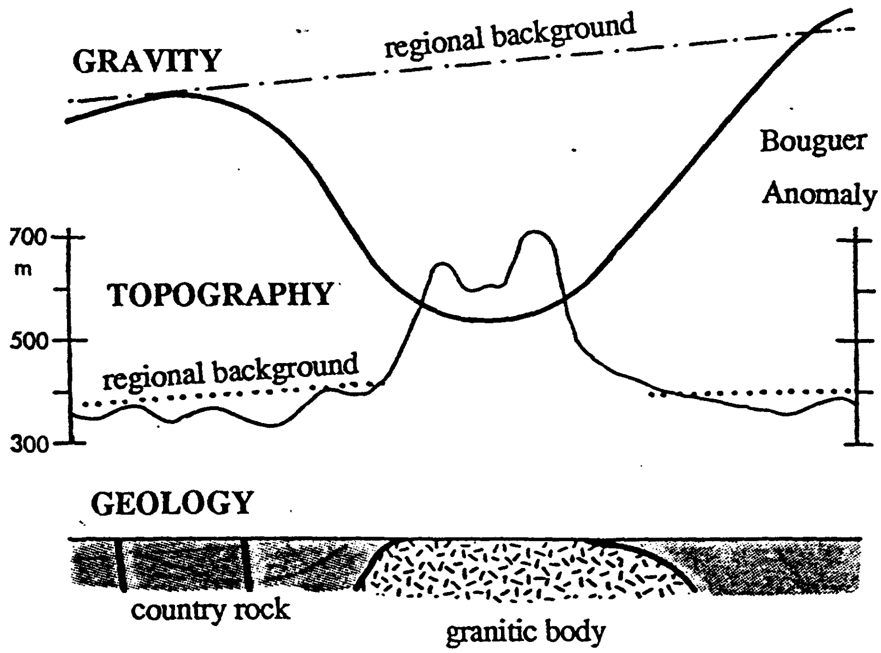

Fig. 6. Bouguer Gravity anomaly across the Del'begetey intrusion (*18*). Profiles of the geology (lower), topography (center) and gravity (upper), run from SW to NE. Gravity and topographic amplitudes are shown relative to the regional background; gravity units were not supplied in the original reference.

CONCLUSIONS

In conclusion, the NRDC seismic stations have been placed atop granitic intrusions that are all roughly the same size and composition, and are all less dense and seismically slower than the surrounding country rocks. These intrusions are all located in similar tectonic and geophysical settings, both in relation to each other and to Degelen mountain, in the Soviet nuclear testing ground. The Karasu site is apparently located in a region where the crust is somewhat different than at the other two sites; Degelen may be expected to be transitional between this site and the other two.

The geologic similarity between these station sites and Degelen mountain provides an unexpectedly solid basis for considering reciprocity relationships for seismic waves recorded at these sites that have emanated from explosions of known size at other test sites where explosions from Degelen are recorded. However, geologic differences between the Degelen testing area and other portions of the Soviet nuclear testing ground (compare references *5* and *10*) may limit the usefulness of indiscriminately comparing NRDC records with seismic data from other test areas within the nuclear testing ground. Further work, comparing and combining data from the three sites with published data for Degelen, may help to build a convincing picture of the details of the structure, petrology and physical properties of the Degelen intrusion itself, which may help to better define the structures responsible for the peculiarities of seismic waves emanating from this nuclear testing area.

Acknowledgements. I would like to acknowledge helpful discussions with J. Rachlin, R. Matzko, R. Wesson and H. Eissler. The manuscript was reviewed by J. Rachlin and R. Matzko.

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