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SEISMICITY AND TECTONIC STRESS FIELD OF THE LAPTEV SEA SHELF

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Abstract

The seismicity of the Laptev Sea shelf, Arctic Ocean, northeast Russia (Fig. 1), is primarily concentrated in three north-south to northwest-southeast striking bands that link the mid-ocean Gakkel Ridge (Arctic Mid-Ocean Ridge) to the active deformation belts of the Verkhoyansk and Chersky Ranges. The main band extends from Gakkel Ridge to Yana Bay with events of magnitude 5.5-7.0, and is presumed to represent the main boundary between the North American and Eurasian plates (Fig 2 and 3).

There are two zones of weaker seismicity parallel the main band. In the West, the Lena–Taimyr zone follows the western edge of the Laptev Sea shelf and extends from the Lena River delta to Taimyr Peninsula. Over 300 weak earthquakes have been recorded from this zone over the past 50 years. The other seismic band is located to the east in the area of the New Siberian Islands and the East Siberian Sea. This is considerably less active than the Lena-Taimyr band with only a few dozen weak earthquakes in 60 years.

All reported focal mechanisms for the Laptev Sea were analyzed for reliability. Most of the events have a normal faulting to transtensional focal mechanisms. We analyze in detail the focal mechanisms of three significant evens (Fig. 5): the 1963 Delta River (Magnitude 5.0), the 1973 New Siberian Island (Magnitude 4.9) and the 1990 Taimyr (Magnitude 5.0).

The western bands are presumed to bound the region of active extension in the Laptev Sea rift system and delineate a Laptev Sea block. The thrusting in the East Siberian Sea and the Taimyr may be a result of the reactivation of olds suture zones resulting from the ridge induced compression in the adjoining continents.

Figure 1. Location map of the study area.

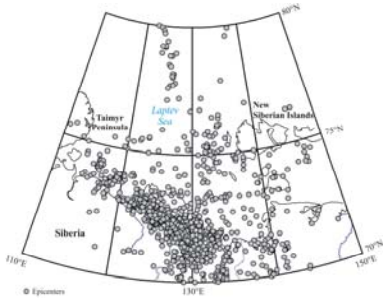

Figure 2. Seismicity in the Laptev Sea Region. Between 1970 and 2003, 1301 earthquakes were located by local and regional stations.

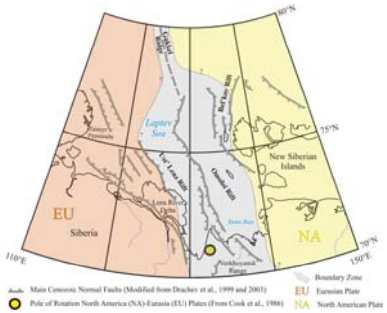

Figure 3. Tectonic setting of the Laptev Sea Region. The boundary zone between Eurasian and North American Plates is a broad region where the at least three main grabens are located: The Ust'Lena, Omoloi and Bel'kov.

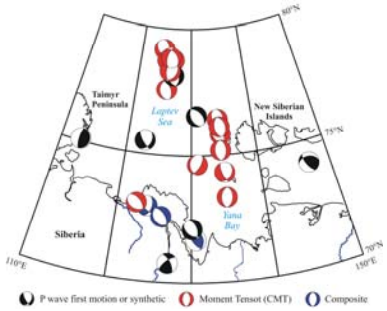

Figure 4. Reliable focal mechanisms for the area.

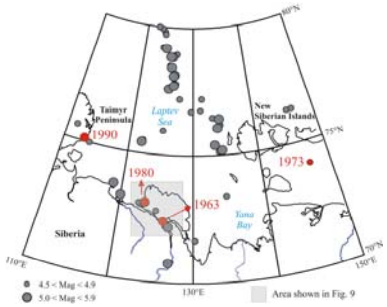

Figure 5. Teleseismic events (magnitudes greater than 4.5) recorded during the period 1970-2003. Epicenters in red are significant events shown in figures 6-10.

Focal Mechanism Analysis and Discussion

All reported focal mechanisms for the Laptev Sea were analyzed for reliability to develop a list of preferred mechanisms. Only solutions for which data were presented were considered, although other mechanism solutions were tabulated for consistency. Figure 4 shows the focal mechanisms considered reliable.

Mechanism solutions determined from short period P-wave first motions were often disparate and contradictory. In particular, solutions using bulletin-reported first motions tended to be biased to having a strike slip component, possibly because stations at large teleseismic distances (> 50 degrees) may not observe/report the true first motion, especially if the first swing is weak. P-wave first motion mechanisms for events with M < 5.2 for northeast Russia are considered reliable only if regional network data are available with a good azimuthal distribution. For the Laptev Sea, Yakut data tend to fall only in one quadrant and therefore usually do not contribute significantly to constraining the solution.

We have chosen the CMT and/or long-period waveform modeling solution as being the most reliable. CMT solutions for the Laptev Sea are surprisingly consistent. Although some tensor components can be poorly determined for shallow focus earthquakes, the Harvard mechanisms for the entire Laptev Sea are extremely consistent, both with each other and with first motion and synthetic seismogram solutions. Synthetic seismogram solutions, in particular those using long period data are in agreement with each other and with CMT solutions of nearby events.

Although essentially all mechanisms in the Laptev Sea indicate roughly east-west extension, a few mechanisms are different. Analysis by different researchers of the 1963 Lena River Delta event using P-wave first motions indicate normal faulting, but with different stress orientations (Figures 6 and 9). However, it is possible that the 1963 event actually has a mechanism similar to the nearby 1980 event which has a CMT solution indicating northeast-southwest directed extension. Two other mechanisms on the extreme east and west edges of the Laptev Sea are both thrust events. Figure 7 shows the 1973 thrust earthquake in the New Siberian Islands. Figures 8A and 10 depict the 1990 Taimyr Peninsula thrust event. It is difficult to explain the occurrence of these two thrust events, but they may be related to ridge "push" stresses adjacent to the rift zone.

Significant Events

1963 Delta Lena River

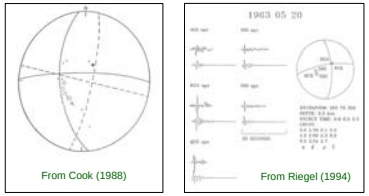

Figure 6. Focal mechanism of the 1963 Delta Lena River Event (5.0 Magnitude). Solid line mechanism of Cook (1988) agrees with regional stresses (NE-SW) extension and high strike-slip component

1973 New Siberia Islands

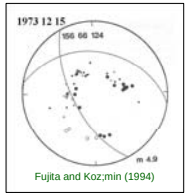

Figure 7. Focal Mechanism from the New Siberian Islands event (4.9 Magnitude). This mechanism is constrained by first motions from the Alaska network, the Yakutsk network, and the WWSSN. This solution shows a Thrust Fault.

1990 Taimyr Peninsula

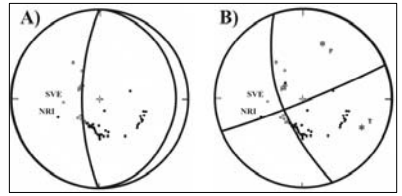

Figure 8. Focal mechanism of the 1990 Taimyr event (5.0 Magnitude). The 1990 Taimyr event can be interpreted as a thrust (Fig. 9A) or strike-slip (Fig. 9B). This is dependent on whether the polarity at NRI (Norils'k) or at SVE (Sverdlovsk) is treated as inconsistent. Treating the event as a thrust allows for the interpretation that it is due to compression induced by rifting in the Laptev Sea. The strike-slip solution is more difficult to explain

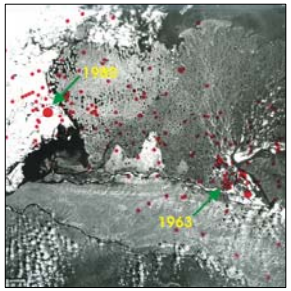

Figure 9. Landsat image of the eastern part of the Lena Delta River. Epicenters of earthquakes (1900-1994) are superimposed. The 1963 event (Magnitude 5.0) is closer to the edge of the platform than the 1980 sequence, which is normal with NE-SW extension.

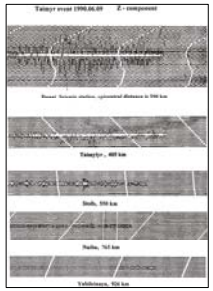

Figure 10. The 1990 Taimyr event (Magnitude 5.0) recorded at Yakutsk Network Stations

Conclusions

Reliable focal mechanism data indicate E-W extension in the Laptev Sea Region. The Gakkel Ridge is characterized by all normal faulting mechanisms with the T-axis oriented perpendicular to the ridge axis. Larger seismicity is concentrated along three grabens located in the Laptev Shelf: Bel'kov, Omoloi, and Ust'Lena grabens. The Bel'kov graben is characterized by most of the reliable mechanisms that we find for the region. All mechanisms are normal faults with E-W extension, perpendicular to the strike of the graben. In the Omoloi graben we find only two reliable focal mechanisms located on the northern part of the graben. Both indicate normal faulting with E-W extension perpendicular to the ridge. Only one significant event has occurred on the Ust'Lena graben. Its focal mechanism shows one of the nodal planes parallels the NW-SE strike of this graben. The Ust'Lena graben historically was thought to be the locus of primary activity, however, seismicity indicates otherwise.

Based on the solutions of reliable focal mechanisms we proposed that the Lena Delta-Taimyr zone is under NE-SW extension.

The thrusting in the East Siberian Sea and the Taimyr Peninsula may be the result of the compression induced from the extension in the ridges to the adjoining continents.

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