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Explosion Contamination of the Northeast Siberian Seismicity Catalog: Implications for Natural Earthquake Distributions and the Location of the Tanlu Fault in Russia

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Abstract Russian regional seismicity catalogs, including those in the annual "Earthquakes of the USSR," are contaminated by industrial explosions. In northeastern Russia, explosions occur in tin, coal, and gold mines, as well as in the construction of roads, railways, and dams. Most seismically recorded mining- and construction-related explosions have magnitudes of about 2.0 and occur during local daytime. In addition, explosions in placer mining areas are concentrated from midwinter to early spring, when frozen placers are broken up for the summer processing season. We analyzed the temporal variation of over 87,000 events occurring in northeast Russia using a newly compiled seismicity catalog to identify areas where there may be explosion contamination. Areas with temporal biases indicative of mining or other explosions include the Yana River delta and Chukotka (placers), the southern Amur district (coal mining), the trace of the Baikal–Amur railroad (construction), Lazo (quarry), the south Yakutian gold fields, and the Kolyma gold belt. The locations, and estimates of the level, of explosion contamination of the catalog suggest that the natural seismicity may be lower, and not as diffuse, along the plate boundaries in northeastern Russia than previously thought. Use of only nighttime events from the seismicity catalog, which should have a minimum of explosions, helps to clarify the extension of the Tanlu fault into Russia and may ultimately help elaborate tectonics in other areas of eastern Russia.

Introduction

Northeastern Russia is one of the most poorly studied seismically active regions of the world. The complex plate interactions between the North American, Eurasian, and Pacific plates and a number of microplates between them, such as Okhotsk, Amur (North China), and Bering (Fig. 1), control the natural seismicity of northeast Russia and have been previously studied using teleseismic data (e.g., Chapman and Solomon, 1976; Koz'min, 1984; Fujita *et al.*, 1990a,b; Imaev *et al.*, 1990; Riegel *et al.*, 1993; Seno *et al.*, 1996; Fujita *et al.*, 1997; Mackey *et al.*, 1997; Imaev *et al.*, 2000). The majority of the seismicity occurs within the Stanovoi seismic zone, on the Eurasia–Amur boundary, and the Chersky seismic belt, on the North America–Okhotsk boundary (Fig. 1). Unfortunately, contamination of the regional seismicity catalog with anthropogenic sources results in an erroneous perception of the level and location of natural seismicity, as well as inaccurate seismic risk assessment. In this article, we present an analysis of the temporal distribution of earthquakes in eastern Russia, based on a newly compiled seismicity catalog, investigating the locations of possible explosion contamination. We then examine the possible implications of this contamination for tectonics studies using the extension of the Tanlu fault in the Amur region of Russia from China as an example.

Data Sources

The database used in this study is a new seismicity catalog for northeastern Russia compiled by combining data from several Russian and U.S. regional seismic networks, as well as the international teleseismic data set (Mackey, 1999). Data were incorporated from all of the Magadan, Yakutsk, Amur, Sakhalin, Kamchatka, and western Alaska regional seismic networks and a part of the Irkutsk network (Fig. 1). Teleseismic earthquake parameters were obtained from a variety of traditional sources, such as the International Seismological Summary (1928–1963), the International Seismological Centre Bulletin (1964–1997), Kondorskaya and Shebalin (1982), and the USGS *Preliminary Determination of Epicenters* (1973–2001). Historic teleseismic data for the re-

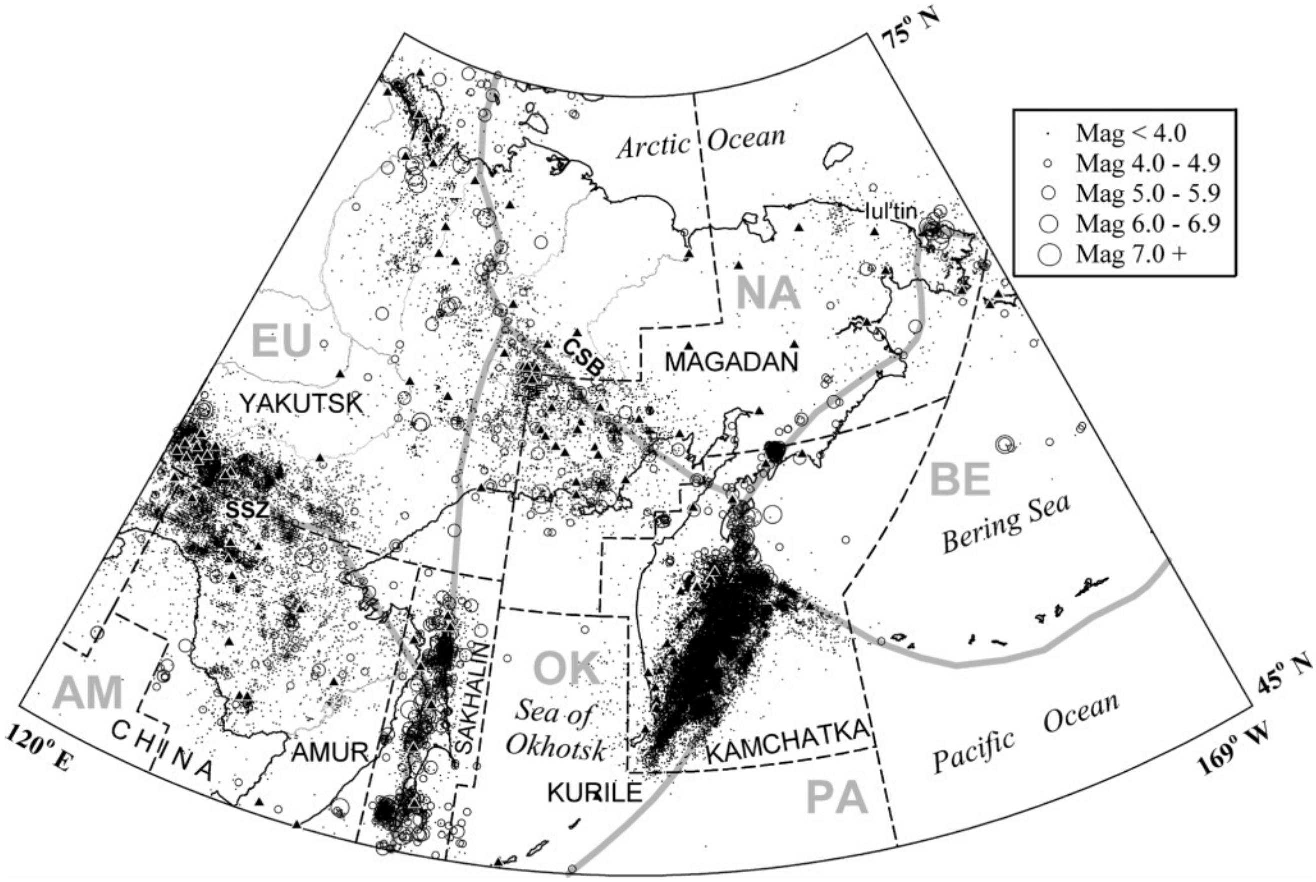

Figure 1. Seismicity, tectonic, and index map of northeast Russia. Heavy gray lines denote boundaries between plates and blocks (Eurasia, EU; North America, NA; Pacific, PA; Okhotsk, OK; Amur, AM; Bering, BE). Black dashed lines denote boundaries between regional seismic networks. Seismicity associated with subduction along the Aleutian and Kurile Islands is omitted. Small arrows show presumed relative plate motions, and the crosshatched circle shows the approximate North America–Eurasia pole of rotation (after Fujita *et al.*, 1997). (Chersky seismic belt, CSB; Stanovoi seismic zone, SSZ).

gion outside Kamchatka begins in the 1920s, when several magnitude 6–7 events were recorded.

Microseismicity in the region went essentially unobserved until the establishment of several regional seismic networks beginning in the mid 1960s. Mackey (1999) used seismicity listings from *Materialy po Seismichnost' Sibiri* (Academy of Sciences of the USSR, 1970–1991) for the Magadan, Yakutsk, Irkutsk, and Amur regional networks and the *Seismologicheskii Byulleten'—Dal'nego Vostoka* (Academy of Sciences of the USSR, 1973–1988) for the Amur, Kamchatka, and Sakhalin networks. These two locally distributed catalogs are based on data from unpublished regional network bulletins, include seismic events as small as magnitude ~1.5, and have virtually identical reporting standards. We also used the unpublished regional network bulletins from the Magadan (1977–2000), Yakutsk (1981–1997), and Kamchatka (1962–1998) networks to obtain more recent epicenters, as well as times and approximate locations of several thousand mine blasts. For the Bering Strait region, microearthquake data were also taken from the western Alaska network (Biswas *et al.*, 1983) of the University of Alaska. A total of approximately 87,500 earthquakes are tabulated in the combined catalog. Duplicate events were eliminated, and some events were relocated using data from multiple networks (Mackey, 1999). Although there is some variation in the detection threshold both spatially and temporally, the data set is relatively uniform for the 1970–1997 time period when the vast majority of the microseismicity was recorded. Based on magnitude versus number of event relationships, the catalog has a completeness threshold of magnitude ~2.75 (converted from Russian K class based on a regional regression of $K = 3.04 + 1.83M$) for most of northeast Russia and magnitude 3–4 for western Alaska. Earthquakes of magnitude ~3 and greater in the *Materialy* and *Seismolgicheskii Byulleten'* catalogs are also listed in the catalogs appearing in the internationally distributed summary annual *Zemletryaseniya v SSSR* (Nauka, 1963–1989; Russian Academy of Sciences, 1990–

1991) and its successor publication, *Zemletryaseniya Severnoi Evrazii* (Geoinformmark, 1992–1994).

Nominal location errors vary from ± 10 to ± 50 km, depending on the station distribution and epicentral location. However, based on relocations performed by Mackey and Fujita (2000), the epicentral error is less than ± 20 km.

Explosion Contamination

Although the regional networks operating in northeastern Russia have attempted to discriminate between industrial explosions and earthquakes, all regional seismicity catalogs containing events of magnitude less than 3.5 are contaminated with explosions related to the breakup of placer deposits, coal, tin, and gold mining and major construction projects (dams, railroads). Early attempts at explosion discrimination in the mid 1970s in the Magadan region consisted of station operators simply removing events within a particular radius of certain mining regions (V. N. Kovalev, personal comm., 1996). Of course, this also removed tectonic events and resulted in peculiar "rings" of seismicity (Riegel, 1994). Beginning in the 1980s, local seismic station operators attempted to discriminate local events (up to 50–70 km distance) based on waveform characteristics and information from the mining companies. Unfortunately, not all mining companies were willing to provide information on their blasting activities, and waveform discrimination proved unreliable at the time.

Identifying explosion contamination in the seismicity catalog was also undertaken by Godzikovskaya (1995), who identified several regions of explosion contamination, specifically in the Zeya basin region of Amur, near the Kolyma and Ust' Srednekan dams on the Kolyma River, and the Polyarnyi mining district in Chukotka. However, many regions and trends of contamination were not identified because of an incomplete seismicity catalog. Odinets (1996) studied the problem of explosion contamination in the Kolyma region and determined that a large fraction of earthquakes reported in the central Kolyma region were actually explosions. Industrial explosions locatable by the Russian regional networks generally have magnitudes of about m_b 1.5–3.0 (converted from Russian K class) and occur during local day (Godzikovskaya, 1995; Odinets, 1996). Placer deposit explosions are also concentrated during the late winter and early spring, when frozen ground is broken up for the summer processing season. While ideal, reanalysis of waveform data for all reported earthquakes would require an unrealistic re-examination of several hundred thousand analog seismograms. However, an estimate of the location and a qualitative level of explosion contamination can be obtained by examining the spatial, size, and temporal characteristics of earthquakes located by regional networks.

Examination of temporal biases in seismicity can indicate potential regions of explosion contamination, since blasting generally occurs during the day (Agnew, 1990; Wiemar and Baer, 2000; Taira and Tsumura, 2001). Unfortunately, unlike standard mining practice in the United States, blasting in northeast Russia is not confined to a specific time of the day, such as noon, but may occur at any time during the workday. Thus, we separated events into 12-hr "day" and "night" segments. However, a small, but not statistically significant, number of explosions are also known to occur during the night hours in many locations throughout the study area (Godzikovskaya, 1995). The study area was divided into 0.5° (latitude) $\times$ 1° (longitude) cells in which the percentages of daytime earthquakes were calculated (Fig. 2). North of 64° N, the cell size was increased to 0.5° $\times$ 2°. Cells containing fewer than ten events were not considered to be statistically significant and thus were not analyzed. As there are five time zones spanning the region, the 12-hr local day period was shifted accordingly. We then focused on cells that had a high bias toward daytime events. We also examined the seasonal dependence in several areas. For this purpose, winter is defined as the 6-month period from the beginning of December to the end of May.

Dark gray areas in Figure 2 represent regions where seismicity is more or less balanced between night and day, and light gray areas are those in which seismicity is concentrated during local night. There are several areas of nighttime-biased seismicity, most of which are in seismically less active regions and/or away from seismic stations. Bias of seismicity to local night is not unexpected, since almost all regional seismic stations in the study area are located in buildings in populated areas and thus have lower cultural noise levels during the night. Analysis of the 1989 South Yakutia aftershock sequence confirms the better conditions of nighttime recording; of 3492 located earthquakes, 1815 occurred during local night and 1677 during local day. Similarly, more events are located at night than during the day in Kamchatka, a region dominated by tectonic activity, at all magnitude levels. In northeast Yakutia, outside the gold mining district, and in nonindustrial areas of the Amur district, there are more nighttime events than daytime events, especially for magnitudes less than 2.5.

Black areas on Figure 2 represent regions where more than 65% of the seismicity occurs during local day. Many of the cells with predominantly daytime events contain discrete clusters or trends of seismicity, most of which can be associated with mining- or construction-related blasting. Several clusters of reported seismicity in the Amur region have more than 90% of the events occurring during local day. Our cutoff of 65% daytime events is slightly more restrictive than that used by Wiemar and Baer (2000), who used 60% daytime events (their $Rq > 1.5$; our cutoff corresponds to $Rq = 1.86$). While there are some temporal variations in detection threshold, especially in the early 1990s when stations were closed due to budgetary constraints, any increase in the detection threshold would decrease the number of explosions recorded and, therefore, daytime events, since mine blasts are concentrated at lower magnitudes. Thus, our 65% cutoff is a conservative indicator of the *locations* of explosion contamination. However, the

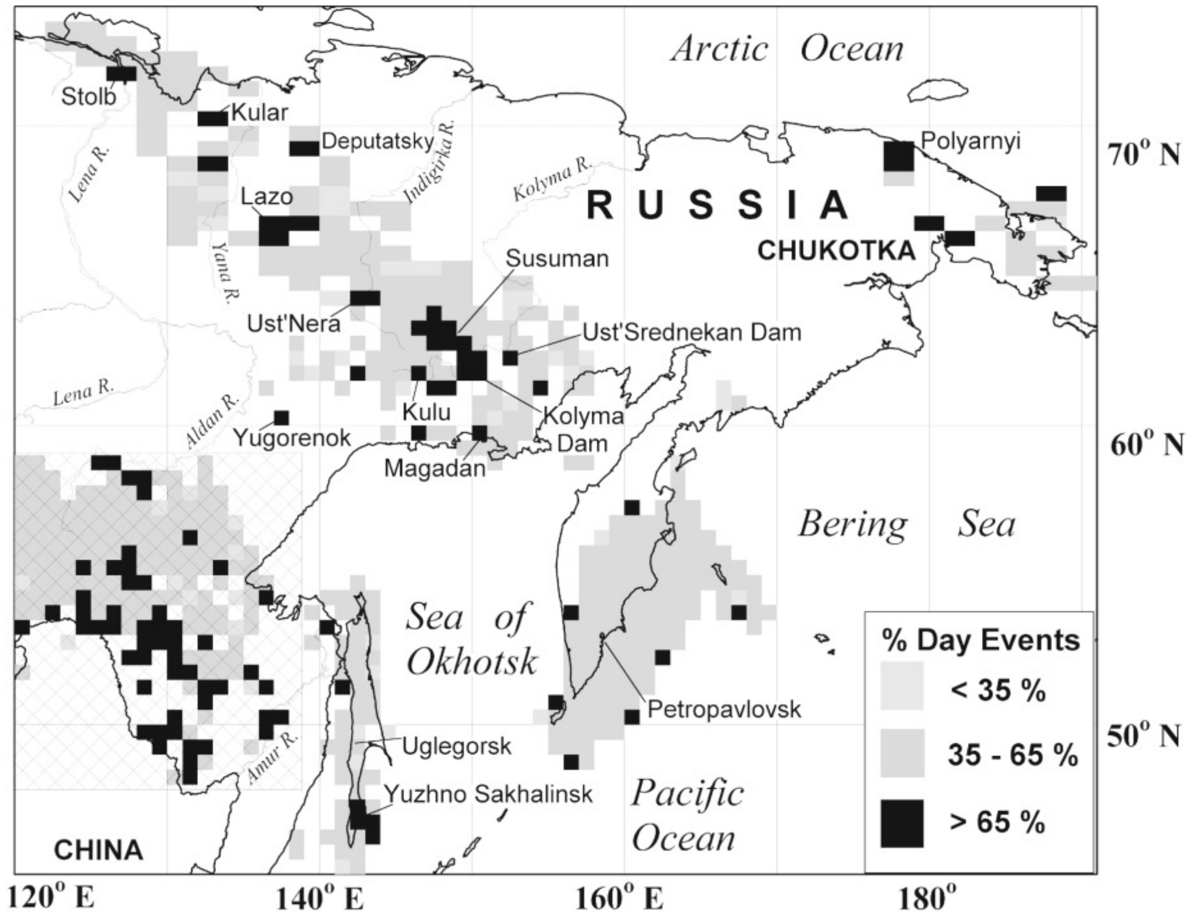

Figure 2. Percentage of seismicity occurring during local daytime for the entire catalog for cells defined in the text. Cells containing 65% or more events in daytime are shown in black and presumed to have explosion contamination. Labeled regions are discussed in the text. Seismicity associated with subduction along the Aleutian and Kurile Islands was not evaluated. The crosshatched area encompasses the southern Yakutia and Amur regions discussed in the text and shown in Figure 3.

exact *amount* of contamination likely varies from place to place and time to time.

For a few cells, we are unable to associate predominantly daytime seismicity to explosion sources. Most of these cells are a result of the random statistics of small numbers, as they are generally close to the ten-event cutoff. In the following sections, we discuss several regions of daytime bias that can be related to explosion contamination with a high degree of certainty.

Amur District

The clearest examples of explosion contamination are in the Amur District (south of 56° N on Fig. 3A,B). If “daytime” and “nighttime” epicenters from the entire catalog are plotted separately (Fig. 3A,B, respectively), we see some distinct differences. Within daytime-biased cells (Fig. 2), there are clusters or trends of seismicity (boxes on Fig. 3) that correlate geographically with specific mining regions or construction activity, and many of these regions have seismicity changes with season. These clusters and trends have very few, if any, events of magnitude 4 or larger. Figure 4 shows the variation in number of events as a function of time of day and month for the two specific clusters. Figure 4A corresponds to the Khingansk tin and iron mining region and shows seismic activity occurring year-round, but almost exclusively during the day. Figure 4B for the Raychikinsk coal mining region indicates events also occurring primarily during daylight hours, but mostly during the winter months. In the north-central portion of Figure 3A, there is a northwest–southeast trend of predominantly daytime seismicity extending several hundred kilometers. This correlates with the route of the Baikal–Amur mainline railroad, and we suggest that these are explosions associated with its construction in the 1980s. We also note that most events are located slightly west of the railroad, indicating possible systematic errors in the location procedure. A second, but smaller and more westerly, trend located about 200 km to the northwest is also associated with the railroad. Many additional discrete clusters of seismicity throughout southern Amur are associated with areas of coal and gold mining (boxed areas in

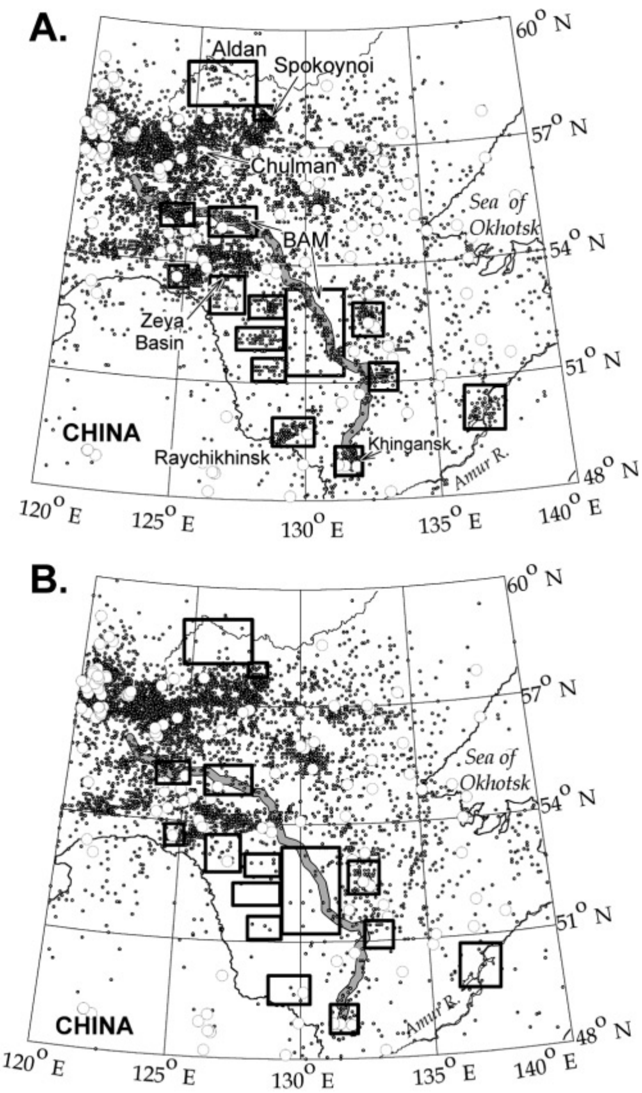

Figure 3. (A) Daytime seismicity of the Amur region, and (B) nighttime seismicity of the Amur region, based on the complete seismicity catalog. Boxes denote actual clusters of daytime-biased seismicity and do not correspond to larger grids of Figure 2. Note the correlation between daytime seismicity and the Baikal–Amur mainline (BAM) railway (gray line). In general, nighttime seismicity better reflects tectonic trends. Locations of data used in Figures 4 and discussed in the text are noted in A. Larger circles represent teleseismic events ($M > 4$) occurring at all times of the day.

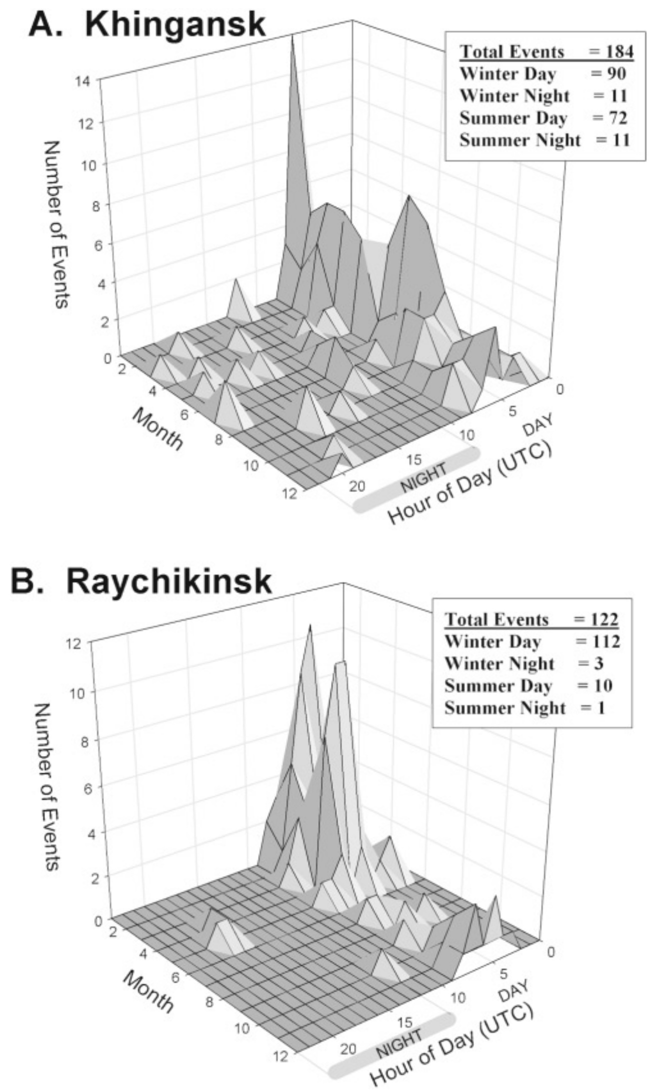

Figure 4. Temporal variation of seismicity in the regions of (A) the Khingansk mine and (B) the Raychikinsk mine. Note that in both regions most events occur between hours 0 and 12 (UTC), which is local day. In B there is also a strong bias for events to occur in the winter months.

Fig. 3). Explosion contamination in the Zeya basin region, in the western portion of Figure 3A, was discussed at length by Godzikovskaya (1995).

If we compare the epicenters of teleseismically located events with the microseismicity, it is found that the teleseisms fall almost entirely within the regions where seismicity occurs in the night. Thus, the nighttime earthquake epicenters appear to more accurately reflect the locations of tectonic seismicity for the southern Amur region, and a different, more northerly trend appears as compared with the entire data set (compare Fig. 3A,B).

Southern Yakutia

Southern Yakutia (north of 56° N on Fig. 3A,B) is somewhat more complicated, as there are tectonic events near mining regions. However, several cells in this area show strong daytime biases, each of which is associated with mining. Additional areas of mining contamination may exist, but the explosions may be masked by the large amount of natural seismicity.

There are three regions in southern Yakutia that have different implications for explosion contamination and the pitfalls of using only a temporal analysis to identify regions of industrial activity. The region around Aldan is associated with a diffuse cluster of predominantly daytime seismicity occurring throughout the year. This is associated with a mining region with extensive deposits of gold and phlogopite mica (Shabad, 1969).

On the other hand, approximately 200 km south of the Aldan mining region is an extensive coal mining region near Chul'man. The seismic station at Chul'man, however, seems able to identify and/or filter most of the explosions; many explosions are located by the Yakutsk network and listed as such in the unpublished catalogs. The temporal distribution of reported earthquakes shows a slight bias toward nighttime events due to this removal of presumed explosions.

Finally, there is a small, but dense, cluster of seismicity near the settlement of Spokoynoi, northeast of Chul'man. Temporal analysis of the cluster shows a strong bias toward winter daytime events from the 1970s through the mid 1990s. Soviet military 1:200,000-scale topographic maps (dated 1986) show extensive mine workings in the region, but list all settlements as uninhabited. The published literature does not make mention of any mining activity in this region, nor does the unpublished Yakutsk network bulletin locate any explosions there. The nature of activity at this location remains unclear, but may represent residual or exploratory mining.

Kolyma Gold Belt and Northern Yakutia

A band of daytime-biased seismicity lies along the Kolyma gold-mining belt (Fig. 2). This region is located just south of the presumed boundary between the Okhotsk block and the North American plate (Riegel *et al.*, 1993; Imaev *et al.*, 1994) and is highly active tectonically. The large number of natural earthquakes makes the statistical separation of anthropogenic sources from tectonic events more difficult. Mining in this region is primarily placer gold, but also includes coal and other minerals. Temporal analysis of the large cluster of events northwest of Susuman indicates a bias toward local day and winter/spring (Fig. 5a). This bias is consistent with the distribution of known explosions from the unpublished Magadan network bulletin for the Susuman region (Fig. 5B), in which the number of nighttime explosions is minimal.

Unlike the seismicity clusters in the Amur region, the clusters in the Kolyma gold belt have a significant number of events occurring during night, most of which are likely to be tectonic events. If we make the assumption that the difference between daytime and nighttime seismicity in Figure 5A is indicative of the level of explosion activity, the approximate percentage of contaminating explosions can be estimated. There are a total of 307 events evaluated in Figure 5A (79% daytime), of which 132 should statistically represent earthquakes (nighttime activity $\times$ 2), assuming the same number of natural earthquakes during the day and night. The remaining 175 events (57% of the events listed in the catalog for this area) probably represent explosions.

The lower level of activity around and to the southeast

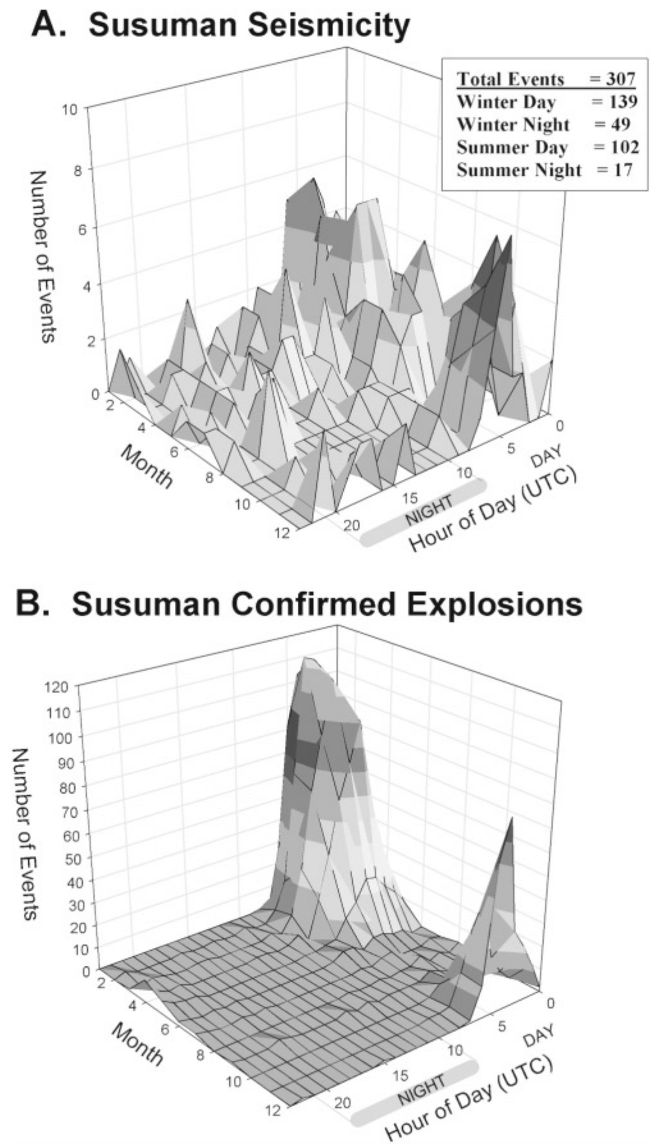

Figure 5. Temporal variation of (A) seismicity and (B) known explosions in the region around Susuman. Note the temporal similarities in the location of the peaks in the figures, which is consistent with many of the reported earthquakes being explosions.

of Susuman is a result of the removal of known explosions by local operators (V. N. Kovalev, personal comm., 1996). Additional explosion contamination in the Kolyma region is associated with gold placer mining near Kulu and Ust' Srednekan and construction on the Kolyma hydroelectric dam (Fig. 2).

The level of seismic activity in northern Yakutia is lower than in the Kolyma region, with much of the seismicity in isolated clusters and regions. Several of the clusters associated with mining regions and having predominantly daytime events are near Lazo (upper Yana River), Ust' Nera (Indigirka River), and Kular (Yana River delta region) with placer gold deposits, the Deputatsky tin deposit, and placer diamond exploration near Stolb (Lena River delta). The gold placer deposit at Yugorenok in east-central Yakutia is also associated with a cluster of daytime events.

Explosion contamination of the seismicity catalog has clearly affected analysis of seismic hazards in the region. Vazhenin *et al.* (1997), citing unpublished materials by T. A. Andreev, showed an increased seismic hazard level in the region north of Susuman, around Kulu, in a trend extending south from Kulu, and near the Kolyma hydroelectric station, all of which are areas of explosion contamination.

Polyarnyi–Leningradsky

Polyarnyi and Leningradsky are placer gold deposits located along the coast of the Chukchi Sea in Chukotka. From 1966 to 1982, most of the events located in this area were single-station locations calculated by the three-component seismic station at Iul'tin (Fig. 1). A clear bias toward winter and daytime is evident for the events in this mining region (Fujita *et al.*, 2002). Comparison of origin times of Iul'tin-located events with the more recent, known explosions from the same mining region yielded a nearly identical temporal distribution, with blasting primarily in the daylight hours of late winter and spring. Note also the distinct lack of teleseismically recorded events around Polyarnyi–Leningradsky as compared to the region a few hundred kilometers to the southeast (Fig. 1). Previous authors have included these explosions in tectonic models (e.g., Lander, 1996) and in assessment of seismic risk (Kovalev, 1989), both of which illustrate the impact of the contamination problem.

Sakhalin Island and Kamchatka

Sakhalin Island shows no clear pattern of explosion contamination, except at the extreme southern tip of the island (Fig. 2). The contamination here is concentrated around the city of Yuzhno Sakhalinsk, where there are likely quarries for road gravel or other stone products. There is also coal mining in the area; however, no bias is observed in the Uglegorsk coal-mining region, which suggests that most coal-mining explosions have been filtered. Kamchatka shows no clear evidence of widespread explosion contamination, although because of the large number of tectonic events, even a moderate level of explosion contamination would be masked by our method. Several dominantly nighttime cells around the perimeter of Kamchatka all fall at or close to the ten-events-per-cell criteria for analysis; thus, they are likely caused by random statistics of small numbers.

Discussion

Identification of explosions and their removal from the northeast Russia seismicity catalog is essential in studying and understanding the tectonics and associated natural seismicity of the region. This is particularly evident in the southern and eastern Amur region (Figs. 6 and 7). Active faults in the Amur region have been summarized in Solonenko *et al.* (1985), Nikolaev *et al.* (1989), and Trifonov (1999), among others, and are plotted on a number of geologic and tectonic maps (e.g., Krasnyi, 1986; Grachev, 1997). If one examines the seismicity map of the southern Amur region, the seismicity appears to form a number of northeast–southwest striking trends that are semiparallel to mapped faults (e.g., Khingan, Kur; Fig. 6). However, some of this linearity in the seismicity is based on the mining contamination represented in the daytime seismicity (Fig. 3A).

Of the faults we have shown in Figure 6, the southern Khingan fault appears to have the best correlation with nighttime seismicity; however, the northward continuation of this seismicity may trend into a north–south trend roughly paralleling the 132° E longitude (Figs. 3 and 7). In the central part of the Amur region, the South Tukuringry fault, as mapped, has some clusters of seismicity along it, but the dominant seismicity trend appears to be at a different strike than the mapped fault (Fig. 6). Overall, however, the mapped faults in the southern and eastern portions of the Amur region do not correlate well with tectonic microseismicity and require further study.

Faults mapped in the northern Amur region and southern Yakutia generally lie in areas with nighttime seismicity, consistent with tectonic activity. The western parts of the Tugur and North Tukuringry faults correspond with well-defined trends in the nighttime seismicity. Seismicity trends are associated with the Atugey–Nuyam fault, various unnamed faults, and the intersection between the Atugey–Nuyam, Gilyui, and Avgenkur–Maya faults (Figs. 6 and 7). Many of the faults mapped in this region are also represented by clear lineations on 1:200,000 topographic maps and *Meteor* satellite images. Linear seismicity trends, which may be represent additional active faults, are visible on Figures 3 and 6.

The dominant seismically active feature in northeastern China is the Tanlu fault system. North of about 41° N, the Tanlu fault system splits into two branches, represented by the Mishan–Fushun and the Yilan–Yitong faults (Fig. 7). We have combined our data set with data from the Chinese national seismicity catalog for northeastern China on Figure 7 to compare activity along these two branches. The northern termination of the Tanlu fault has been generally unclear and mapped in various locations by different authors (e.g., Jiawei *et al.*, 1987; Huang *et al.*, 1996). Jiawei *et al.* (1987) mapped the Tanlu fault as following the Mishan–Fushun fault through eastern China and continuing through the eastern Amur region until terminating near the northern end of Sakhalin Island; this option for the northern extension of the Tanlu fault system shows no correlation with the presumed tectonic seismicity represented by nighttime events (Fig. 7).

On the other hand, Huang *et al.* (1996) mapped the Tanlu as following the Yilan–Yitong fault up to the Russian border near 48° N, 131° E. This correlates almost exactly both in location and strike with the southern termination of a north–south nighttime seismicity trend we identify along 132° E in the Amur region (Fig. 7). We suggest here that the seismicity trend along 132° E represents the active extension

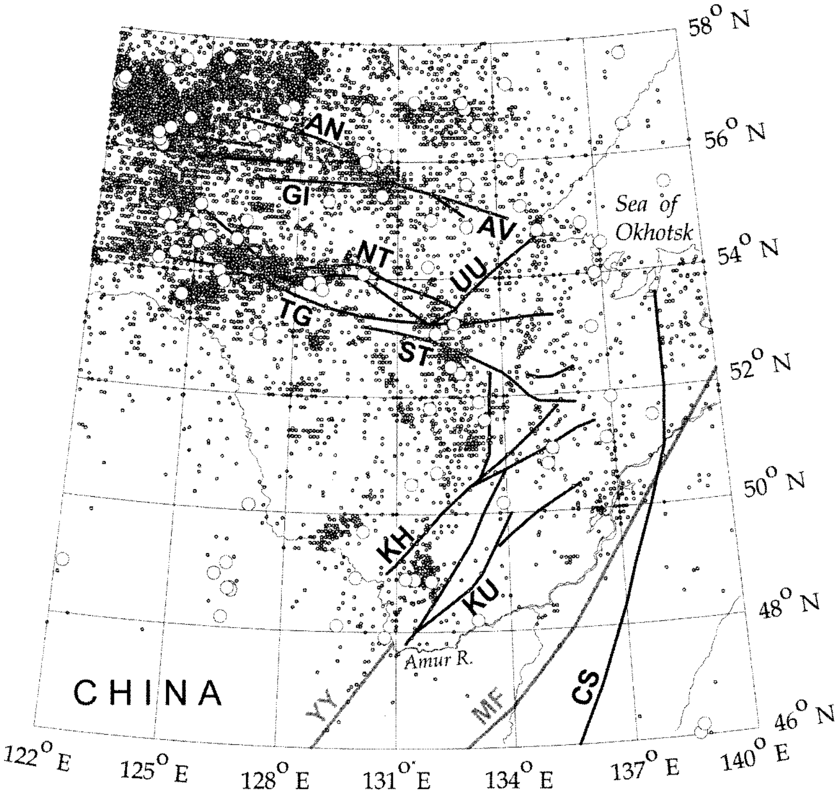

Figure 6. Mapped faults of the Amur region (see text for sources). All events, daytime and nighttime, of greater than magnitude 4 are shown as large circles, while smaller circles depict all the microseismicity. Mapped faults (lines) are Khingan (KH), Central Sikhote Alin (CS), Kukan (KU), Avgenkur–Maya (AV), Atugey–Nuyam (AN), Gilyui (GI), South Tukuringry (ST), North Tukuringry (NT), Ulikim Ulidgan (UU), and Tugur (TG). Additional mapped but unnamed faults are also shown.

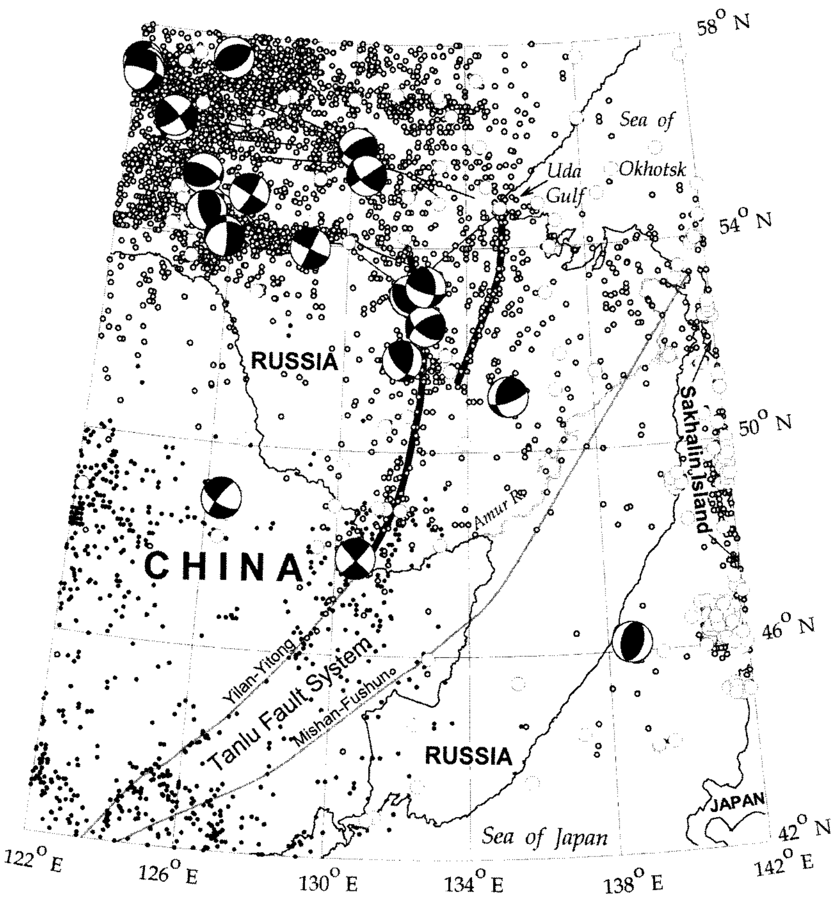

Figure 7. Nighttime-only seismicity of the Amur region and northeastern China showing possible locations of the Tanlu fault. Events from the Russian catalog are shown as small circles, and events from the Chinese catalog are shown as dots. All events, day and night, of magnitude greater than 4 are shown as large circles. North of 51° N, the fault system may split into two segments, as depicted by heavy black lines. Note that the alternate extension of the Tanlu fault system following the Mishan–Fushun fault shows no correlation to seismicity. Focal mechanisms are shown for reference (see text for sources; lower hemisphere projection, compressional quadrants solid). Additional faults in the Southern Yakutia region are depicted as in Figure 6.

of the right-lateral Tanlu fault of eastern China into the Amur region of Russia. In the Amur region, the strike of the fault gradually changes from northeast–southwest in the south to more north–south further north.

Focal mechanisms from the Amur region have been presented in Koz'min (1984), Parfenov *et al.* (1987), Chung *et al.* (1995), the *Materialy* and *Zemletryaseniya* catalogs, and in the Harvard and U.S. Geological Survey centroid moment tensor catalogs (Fig. 7). Focal mechanisms in the northern part of the Amur region are generally consistent with a left-lateral east–west striking transpressional boundary. Focal mechanisms in the central Amur region, along the north–south seismicity trend between 132° and 133° E, indicate predominantly southwest–northeast thrusting, although individual mechanisms vary somewhat and are poorly constrained in some cases. Taken at face value, the available data for the north–south seismicity are consistent with a thrust boundary that, based on the seismicity, represents the primary active tectonic feature in the southern and central Amur district. There are also a few mechanisms in China near southern Amur. One of these strike-slip mechanisms falls near the southern end of the north–south trend through Amur and indicates right-lateral motion.

Combining the seismicity and focal mechanism data, the extension of the Tanlu fault follows the Yilan–Yitong fault to the Russian border. To the north, the strike of the fault changes to a more north–south strike and the motion changes from right-lateral strike slip to southwest–northeast directed thrusting, as shown by the focal mechanisms for the region (Fig. 7). Without removal of the explosion contamination from the Russian seismicity catalogs, and combination with the Chinese seismicity catalog, the clear extension of the Tanlu fault system into Russia is obscured.

A second branch of seismicity, with fewer and weaker events, extends northeast from the 132° E seismicity trend to the head of the Uda Gulf. This may be another splay of the Tanlu system that takes up additional transpressional motion.

Conclusions

Based on a very simple temporal analysis, it is evident that the seismicity catalogs of northeast Siberia are heavily contaminated with daytime industrial explosions. As a first step in reducing the impact of the contamination on the analysis of natural seismicity, the use of a map of only nighttime events provides a better representation of the level and distribution of natural background microseismicity in the region. Such a map also provides for better identification of active tectonics and faulting. As an example, nighttime-only seismicity maps have allowed us to clarify the location of the presently active extension of the Tanlu fault from China into the Amur region of Russia.

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