Burträsk – the most seismically active fault in Sweden

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As the latest Pleistocence ice sheet retreated from northern Fennoscandia some 10,000 years ago tectonic and glacially induced stresses combined to create very large earthquakes. These endglacial earthquakes reached magnitudes of 7 – 8 and left fault scarps up to 155 km long in northernmost Fennoscandia (see review in Lund, 2015). Most of the endglacial faults (EGF) still show considerable seismic activity (Fig. 1) and the area around the Burträsk EGF, south of the town of Skellefteå (Fig. 1), is not only the most sesmically active EGF but also the currently most seismically active region in Sweden (Lindblom et al., 2015).

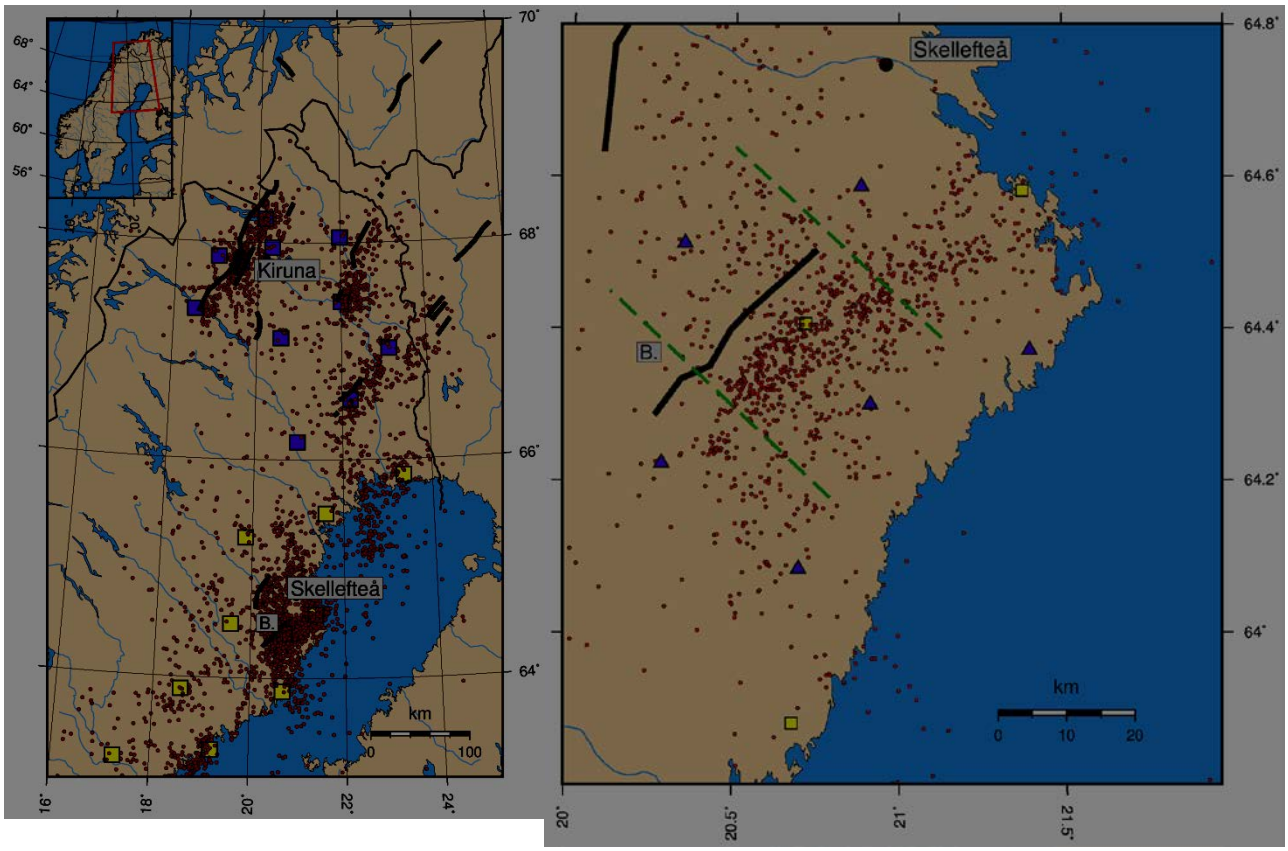

Figure 1. Map view of the seismicity in northern Fennoscandia recorded by SNSN from 2000 till 2014 (Lindblom et al. 2015) to the left and on the right is shown the final catalogue locations for the Burträsk earthquakes recorded between December 2012 and December 2014. The faults are shown with black lines and the (B.) marks the Burträsk fault. The squares represent the permanent stations of the SNSN, the yellow are the stations used in this study, and the triangles are the temporary stations. The green dashed lines in the right map mark the profiles dividing the area into 3 parts (see Figs. 4 and 5).

The modernization of the Swedish National Seismic Network (SNSN) in 2001 instrumented the area with three broadband seismic stations. Aiming at better detection levels and increased depth accuracy a fourth station was installed on the central cluster of events in 2011. The ongoing investigations of endglacial faults at Uppsala University and the Swedish Nuclear Fuel and Waste Management Co. (SKB) resulted in a joint project to study the Burträsk seismicity in detail. A temporary network of six additional seismic stations was installed in the area in late 2012. Continuous waveform data is transmitted in real-time to Uppsala for off-line analysis with the SNSN data. We use 10 stations from the permanent SNSN (see Fig. 1) together with the six temporary stations (Fig. 1) in a local subnetwork for the analysis of the Burträsk seismicity. Here we report on the preliminary analysis of the first two years of temporary data acquisition, from the beginning of December 2012 to the end of December 2014. For this time period 1520 earthquakes have been manually inspected using the automatic event locations from the SNSN SIL seismic processing system. The magnitude of completeness of the catalogue is -0.4 (Fig. 2). For comparison, the SNSN located 722 of the events in the same time period, making for a magnitude of completeness of -0.2.

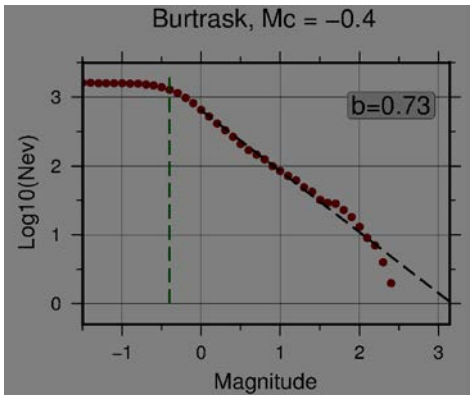

Figure 2. Frequency - magnitude relationship for the earthquakes in the Burträsk dataset.

We use a time-domain cross-correlation technique on the two years of seismic waveform data to find more earthquakes than those automatically located by the SIL system. This process added more than 50 events to the catalogue. The cross-correlation is carried with 22 events as templates. These events are chosen as being representative of similar earthquake clusters, or as members of earthquake doublets. The signals are bandpass filtered between 6 and 12 Hz, with 1 s of length for the P- and S-waveforms starting 0.15 s before the picks. Only events with a correlation coefficient above 0.85 are considered for the identification of new events. A sample of a family of very similar earthquakes, located close to the fault, is shown in Fig. 3.

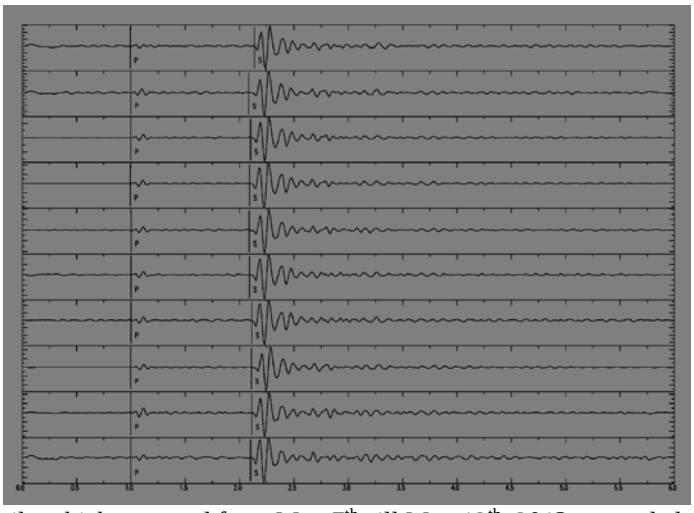

Figure 3. An earthquake family which occurred from May 7th till May 12th, 2013, recorded on the east component at station *ode*, located at the centre of the Burträsk fault. The magnitude range for the events is -1.1 – 0.7.

A new velocity model for the Burträsk area is determined - using VELEST, a software program for derivation of a minimum 1D velocity model and improved hypocentre locations (Kissling et al.1994). In the velocity model derivation, the earthquakes that are used have at least 10 picks and an azimuthal gap of less than 180°. Once the new velocity model is derived, we use the program to relocate all the events in the initial catalogue. VELEST requires the events to have at least 5 picks, which we have for 1480 of the earthquakes.

We use hypoDD (Waldhauser & Ellsworth, 2000) to relocate the events relatively. We use the new 1D velocity model and cross-correlation differential travel times for those events that correlate well, and picked travel time differences for other events. The final epicentral locations are shown in Fig. 1 and on depth sections in Figs. 4 and 5, and they consist of 94 original SNSN locations, 517 events relocated with VELEST, and 961 additionally relocated with hypoDD.

Figure 4 shows that the microearthquakes align on a southeasterly dipping structure. They are not all associated with a single, simple fault plane, instead we see that at depth the events seem to spread out in a northwest-southeast direction. The main structure dips approximately 50-60°, which is similar to the 55° dipping reflectors at shallow depths in the reflection seismic profile of Juhlin & Lund (2011). Comparing Figs. 1, 4 and 5, we note that the seismicity on the southwestern section of the Burträsk fault is very different in character to that on the central and north sections. There is no indication of a steeply dipping structure in the earthquake data there, instead the seismicity seems to occur in a diffuse, relatively shallow zone to the southeast. Further work on relocation and analysis of the data set will perhaps make it possible to discern different classes of event in the depth profile, in order to more clearly image the rupture zone of the endglacial earthquake.

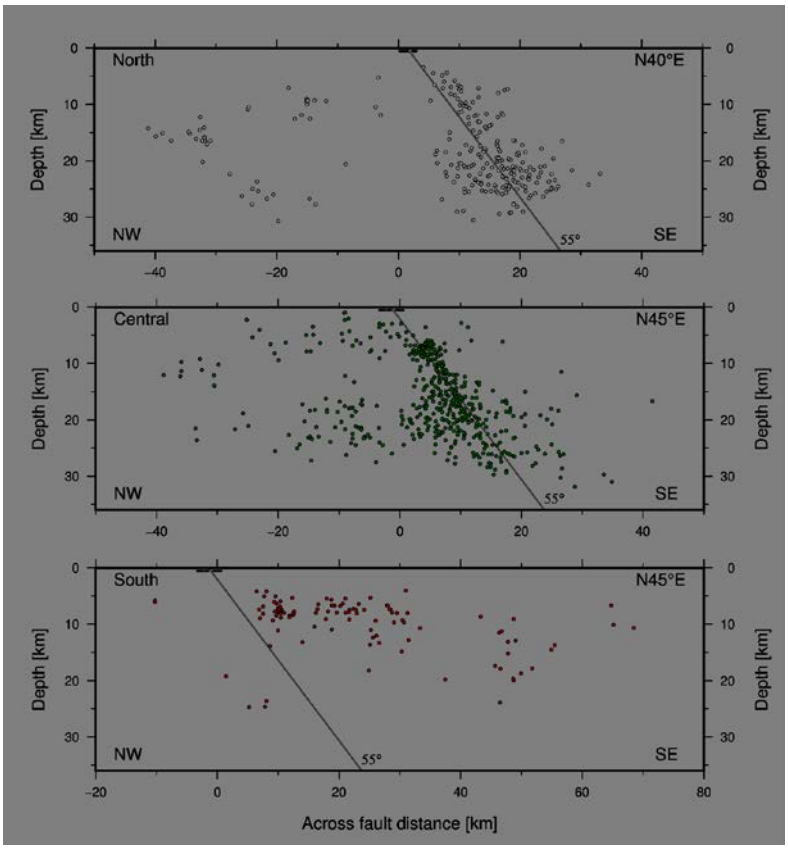

Figure 4. Depth sections of earthquake locations after processing with hypoDD. The dashed green lines in Figure 1 (right) divides the Burträsk area into the three sections presented here. The view is perpendicular to the azimuth of the fault – N45E, for the southern and central part, and azimuth of N40E is considered for the northern part. A dipping line of 55º is marked on each section. The thick black lines at zero depth mark the location of the Burträsk fault.

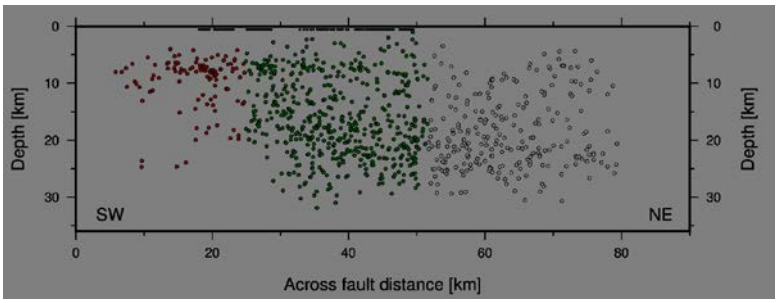

Figure 5. A depth section of the locations along the Burträsk fault. Red, green and white circles represent the events as divided by the profiles in Figure 1(right). The thick black lines at the surface mark the fault location.

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Буртреск – сеизмично най-активният разлом в Швеция

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След оттеглянето на ледниковия щит през последния ледников период в Северна Фенноскандия са възниканли силни земетресения с магнитуд 7-8 и разломни разкъсвания с до 150 км дължина. Тези разломи са активни и до днес, като Буртреският разлом е най-активният от тях. В това изследване са показвани временни резултати, които са базирани на около 1600 земетресения, с пълнота на магнитуда -0,4. Събитията са регистрирани в период от две години от 6 временни станции, разположени по продължението на разлома, и 10 постоянни станции, част от Шведската Национална Сеизмологична Мрежа SNSN в региона. Определен е нов скоростен модел за района и хипоцентрите са преизчислени посредством софтуерните програми VELEST и hypoDD. Сеизмичността в района се простира по продължението на разлома, но и продължава с подобен азимут отвъд картографираната разломна линия, достигайки Ботническия залив. Локализираните земетресения сочат за сеизмично активна зона с наклон около 55° на югоизток, със земетръсни огнища до 35 км дълбочина.