NEOTECTONICS RESEARCH IN CANADA

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Western Canada, associated with the active western margin of the North American Plate remains the most critical region for Neotectonics study in Canada because of its implications for natural (chiefly earthquake) hazard assessment. Research has included description of a few active fault traces in the Yukon (Clague) and at the Hat Creek, B.C. (Slemmons), and the as-yet-unsuccessful search for active faulting related to the 1946, 1918 and other large B.C. earthquakes. Above the Juan de Fuca subduction zone, levelling, triangulation, tide gauge analyses, and microgravity surveys on Vancouver Island (by Dragart, Rogers, Riddihough, Wigen and Stephenson, and others), together with similar measurements in Washington and Oregon confirm active subduction and imply the potential for a great thrust earthquake on the plate boundary. Holocene sea level changes (by Clague) are important for placing these historical measurements in perspective. As no great earthquake occurred in the past 150-180 yrs, evidence for previous earthquakes must be sought in the Holocene geological record, both directly through rapid facies changes due to coseismic uplift or subsidence, and indirectly from periodic deposits that might represent slope failures during strong earthquake shaking. In this context, mapping of landslides (as done by Mathews for the 1946 earthquake) or of very large rockslides in the Cordillera (Evans) may contribute to new assessments of earthquake hazard.

By comparison with the west, eastern and arctic Canada are tectonically inactive. Research into non-glacial neotectonics is hampered both by the slow deformation rates and the fact that much of the pre-Holocene evidence was eroded or buried during the last glaciation. Nevertheless, areas of relatively high earthquake activity imply secular crustal deformation and work by Grant on interglacial shorelines in the Maritimes demonstrates a non-glacial component of vertical movement. A recent compilation of crustal stress orientation data (Adams and contributors) has confirmed that Canada east of the Cordillera is being compressed from the NE or ENE, most likely in response to ridge-push from the Mid-Atlantic spreading centre or drag on the base of the North American Plate as it drifts southwest. Although there are local anomalies to be explained, the recognition of this continent-wide stress field indicates a plate-tectonic control for most contemporary neotectonic deformation excluding the residual glacial uplift.

Vertical deformation due to deglacial unloading dominates secular neotectonics in the east and has been documented by Peltier, Vincent, Grant, Andrews, and others. Their continued work will refine crustal rheology models and constrain the mode of deglaciation - parameters necessary for understanding Canadian and world-wide sea level and climate changes in the Holocene. In some places (eg. Great Lakes) the rates are sufficiently high to affect human activities, for example historical uplift of the outlet to Lake Ontario has raised average water levels at the SW end of the lake enough to significantly increase shoreline erosion.

MACROSEISMIC MAP AND ABNORMAL BEHAVIOR OF ANIMALS BEFORE THE EARTHQUAKE OF LIEGE (8.11.83, BELGIUM)

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A macroseismic map compiled by computer after an earthquake of magnitude 4.9 shows that the shock was probably related to the Rhine graben and that coal mining amplified ground shakings. Numerous abnormal animal behaviors were reported to have occured immediately before the quake. Their relative number varied directly with the value of the macroseismic intensity of the map.

An earthquake of Richter magnitude 4.9 and M.S.S. intensity over VII hit the area of Liège (Belgium) on the 8th of November 1983 at 0h50 min. (U.T.). The epicenter was located just under the urban agglomeration and the source was at a depth of approximately 4 km (1).

A few days after the earthquake an inquiry was made with the help of several local schools to look for site effects and to know if animals showed premonitory behavioral signals.

Macroseismic map

1663 answers were collected from the area covered by the maps of the agglomeration (20.2 km x 14.4 km). Information on the damages (fallen chimneys, fissures in walls and ceilings, displacement of furnitures, etc) enable one to give an intensity for each answer. Information was also collected on the age of buildings, the material used in constructions, etc. All the results were submitted to a SAS-GRAPH program carrying out maps of the variations of intensity. Several maps were produced, lying on different rectangular mesh nets and using various corrections for the age of the buildings. They show a great similarity and only one is presented here (figure 1).

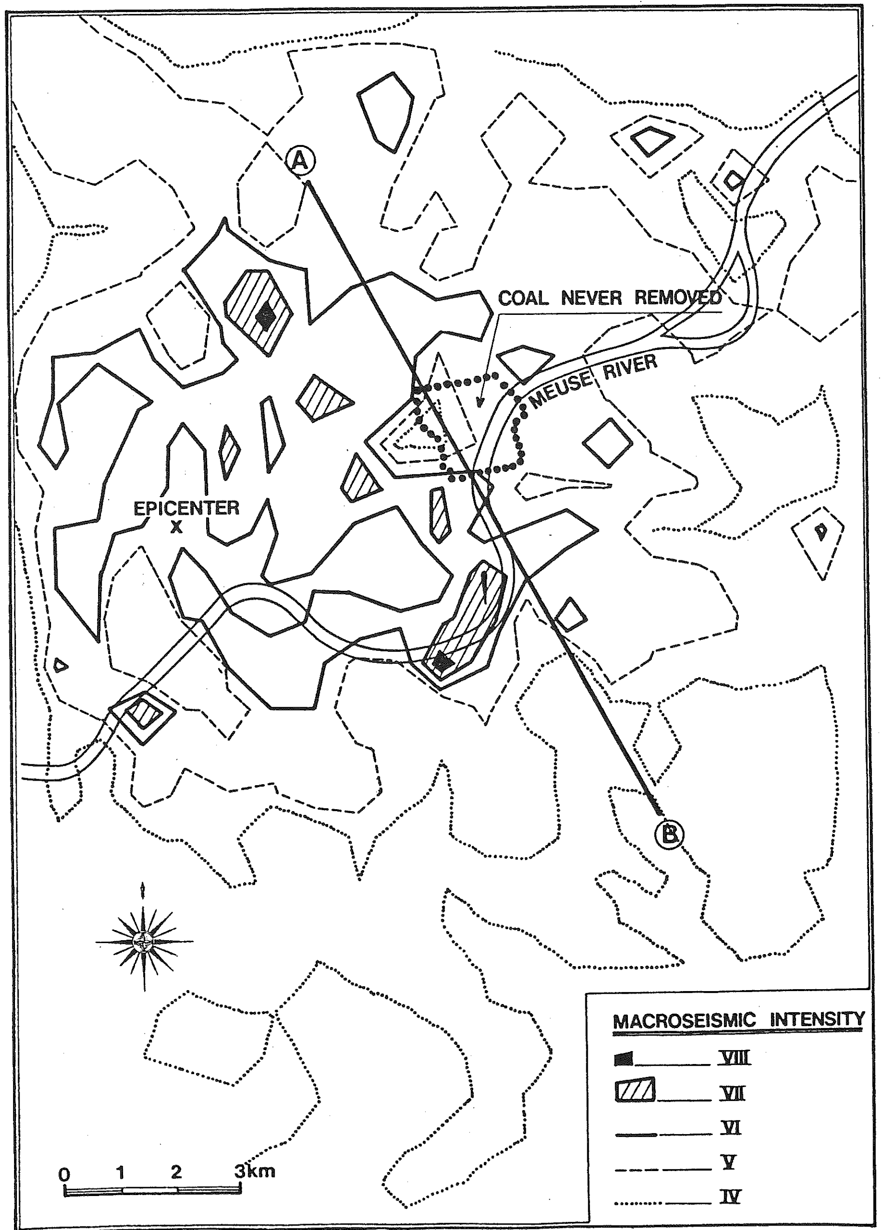

Figure 1. Map of macroseismic intensity compiled by computer after the Liège earthquake of the 8th November 1983.

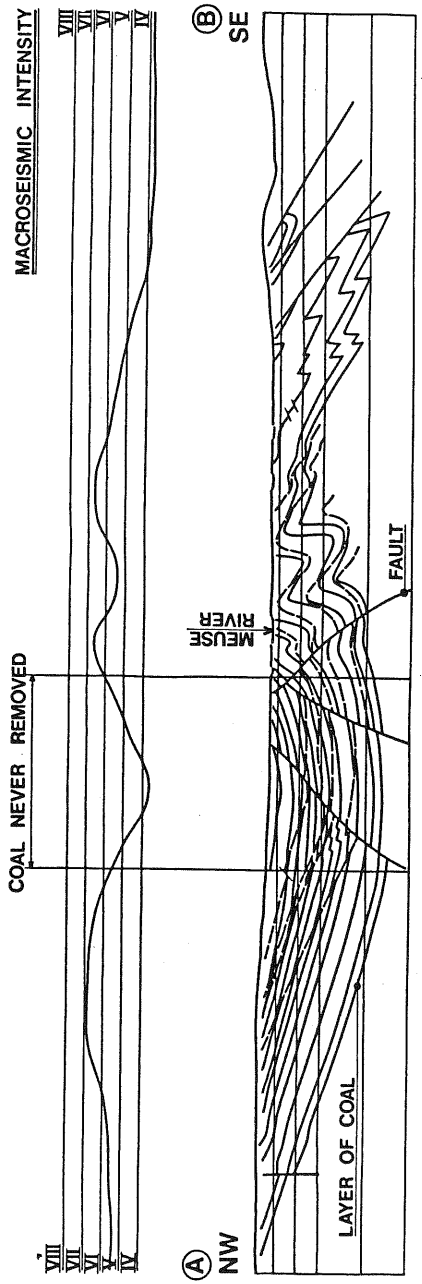

Figure 2. Geological section (ref.3) and macroseismic intensity following the AB Line on the figure 1. The intensity is decreasing at the limits of the carboniferous syncline and also under the old city of Liège where the coal was never removed.

This map shows two interesting features :

1. The zone of highest intensity shows an orientation NW-SE which is exactly the direction of the faults of the neighbouring Rhine graben. The nearest known extension of this graben system is only twenty five kilometers from Liège (2). Consequently, the quake was probably related to a movement of this graben.
2. A break in intensity corresponds with the limits of a synclinal structure involving carboniferous age sediments. Layers of coal have been mined for many years in Liège district. A low in intensity occurs in the middle of the syncline where, under the old city, the coal was never removed (fig.1 and 2), demonstrating clearly that the amplification of the shaking resulted from the mining activity. Details of the maps seem to indicate that the ground shaking was strongest where mining had reached to only a few hundred metres; intensity was lower in areas where excavations had reached greater depths.

Abnormal behaviors of animals

Reports of abnormal animal behavior before the earthquake were collècted during the enquiry, some from places as distant as 100 km from the epicenter. Here, only conclusions resulting directly from observations gained through the questionnaire are presented. We have disregarded many tens of reported cases which were received from other sources. In this way, the result of the enquiry can be regarded as a random sample.

784 answers reported about animals. Of those, 479 did not observe any abnormal behavior while 305 indicated peculiarities. Typical abnormal behaviors were for cats and dogs such as crying and waking their masters before the quake, refusing to eat, and either refusing to go out or unwilling to get out. In addition, cocks crowed during the night and geese cried...

Such abnormal behaviors were reported in a great number of newspapers (4) and for this reason no more details are reported here. Their distribution on the map, however, does not show any relation with the epicenter. On the other hand, if we consider the relation between the number of animal showing reaction to the number of animals without reaction, there is a close

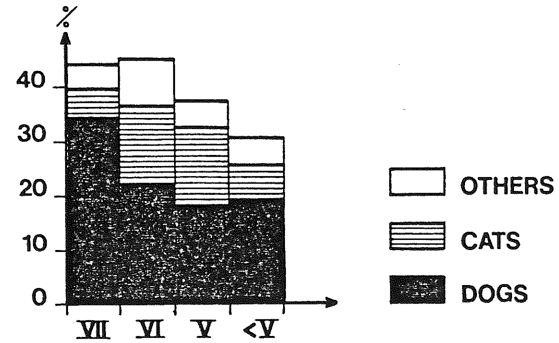

Figure 3. Relation between the macroseismic intensity and the number of animals showing reaction to the number of animals without reaction.

relationship with the macroseismic intensity. For example, 44 % of premonitory behavior occurred within intensities VII and VI (302 animals); 37,5 % for V; and 30,9 % for VI and less (fig.3).

The time of these abnormal reactions before the earthquake, as they were considered by RIKITAKE (5), is given on the figure 4. No variation in the distribution of the premonitory signals with the intensities of the macroseismic map were found.

Nobody presently knows what were the premonitory signals from which animals knew that a quake would happen soon. A study like the present one, in which a great number of reports on animals were collected at the same time that information on their situation before the quake (in or outside; in old house or in modern building with iron frame; at different floors of buildings, etc.) may help identify possible predictive criteria for future earthquakes; it may also be useful to look for the way they are advertised.

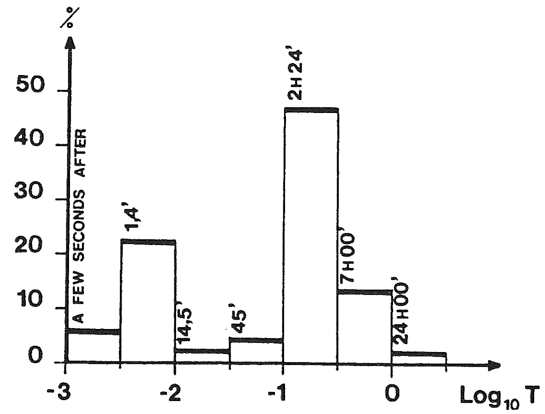

Figure 4. Time before the quake of the reported abnormal animal behaviors.

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NEOTECTONICS ON THE HAUTES FAGNES PLATEAU (BELGIUM)

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The Hautes Fagnes plateau is geologically defined as the Massif of Stavelot, a Cambrian outcrop in the axis of the Ardenne anticline. This plateau belongs to the Rhenish Massif and is situated at the SW-margin of the Lower Rhine Embayment. A study of the planation surfaces of the Hautes Fagnes and of its northern foreland has shown that these surfaces were tectonically deformed during Neogene and/or Quaternary. The present short note is an attempt to demonstrate the existence of NW-SE trending radial faults on the Hautes Fagnes plateau whose Cenozoïc activity is connected with the opening of the Lower Rhine Embayment. This conclusion is of great importance to understand the Liège earthquake of 8 November 1983 and its mechanism.

Geological observations are rare and don't permit any conclusion on the recent activity of the faults on the Cambrian massif, so that morphological features are essential. At first, the cretaceous and paleogene planation surfaces indicate that radial faults were active in the region after Oligocene times, since both paleotopographies are similarly deformed by NW-SE tectonic irregularities in many places. Tectonic scarps appear also in the actual landscape, aligned in a NW-SE direction on the Hautes Fagnes crest (a-e, fig.1) and in the northern foreland of the plateau (f., fig.1). Furthermore, several sections of river valleys indicate the presence of NW-SE fracture lines on the massif (a, g-k, fig.1), as derived from their morphology and their evolution. The radial fault zones deduced from these morphological observations are confirmed by the presence in their alignment of faults in the Devonian and Carboniferous foreland of the Hautes Fagnes plateau. Consideration of earthquakes in the eastern part of Belgium is also in agreement with the proposed faults.

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