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See table of contents

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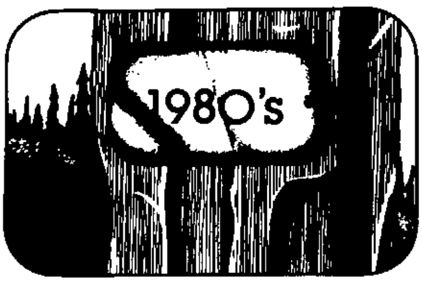
Discussions



Canadian Earth Science in the Eighties

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First, I would like to compliment the Editor for the quality and excellence of the September 1981 issue of *Geoscience Canada* just received. I read it cover-to-cover, and found it most informative and enjoyable. It represents the work of many earth scientists, and their efforts are greatly appreciated. I would like to comment on every one of the articles and individual reports, but space precludes this. Accordingly, I have selected two points for discussion. Both are contained in D.J. McLaren's article: *Earth Science and Federal Issues* (McLaren, 1981, vol. 8, p. 106-112).

COCORP Vibroseis Profile Across the Southern Appalachians

The Deep Earth: Geology in the Third Dimension, A.G. Green (McLaren, 1981, p. 111 and Fig. 10). There is no denying that the application of the vibroseis has produced spectacular results, especially in the southern Appalachians (see Fig. 10), and has forced many experts to radically change their views. However, the results were not "completely unexpected."

In his Presidential Address to the Geological Society of America and to the Geological Association of Canada, in Ottawa in 1947, A.I. Levorsen (1948, p. 293 and Fig. 8) dramatically demonstrated thin-skin overthrusting of the southern Appalachians and speculated: "The underlying western rocks are known oil and gas producers and may extend far to the east below the soles of the overthrust series." He went on to predict: "Pressure for more oil and gas discovery will provide the incentive for drillig of the deep holes necessary to test the formations below the faults."

Unfortunately, differential entrapment, or gas flushing, will preclude the discovery of any oil in the deeper reservoirs below the sole fault. The same applies to "Canada's young mountain belts".

The Grand Bank Earthquake of 1929

Geological Hazards and Constraints on Development: Earthquake Hazards, P.W. Basham (McLaren, 1981, p. 107 and Fig. 3). Was the Grand Banks slump induced by an earthquake? . . . for that matter, what was the cause of the great Alaska earthquake of 1964?

Both were submarine landslides, which caused the earthquake and generated the devastating tsunami that followed, and the landslides were transformed into very large turbidity currents. Because of the fortuitous presence of many submarine cables, the Grand Banks slump and the turbidity current it generated were precisely documented. There were no cables off the Alaska coast.

As a student in 1936, I can well remember Daly's spectacular demonstration at Harvard of a turbidity current. He was sitting on the lecture table and pulled out his fountain pen and casually reached for a glass of water and tilting it, touched his pen to the glass at the water edge, and the blue ink went charging down the slope without any mixing. It was most dramatic and impressive. Daly suggested that turbidity currents might be generated by storm waves, tsunami, and internal waves, or these processes, plus earthquakes may cause slumps and slides which may be transformed into turbidity currents.

Heezen and Ewing (1952) successfully explained the orderly succession of cable breaks from shallow to deeper water as caused by a major turbidity current, but erred in explaining the origin of the slump and the cause of the earthquake. As they pointed out (Heezen and Ewing, 1952, p. 861), a similar event occurred in 1884, and the cable breaks were attributed to "landslides or earthquakes" (Milne, 1897). Heezen and Ewing were convinced "that the Grand Banks earthquake triggered off a very large turbidity current." (1952, p. 870). In 1954, Heezen *et al.* still attributed the cause of the slump to a severe earthquake, and in 1964, Heezen and Drake still held the same view. In 1964, I questioned this assumption which was unsubstantiated by any field evidence (Unpublished Ms, Sept. 8, 1964). Heezen *et al.* (1954, Fig. 1) show the typical, greatly exaggerated profile of the continental shelf, slope and rise, and the abyssal plain, but also show a natural-scale section to a depth of 4000 fathoms. This is 1.5 mm high, and completely eliminates the steep cliff usually indicated on all profiles at the outer edge of the continental shelf. Although an exaggerated profile is necessary to record details and data, it is absolutely essential to use a natural-scale section to be able to visualize the true gradients and relationships. Their Figure 4 is a chart, showing the submarine avalanche area on the continental slope in the vicinity of the epicentre, where many cables sheared off at the slip surface, instantaneously, at the instant of the slump, and the path of the destructive turbidity current which broke in orderly sequence from north to south and carried away successive cables in its path, and swept across the sea floor for well over 375 km, out to the abyssal plain. Out on the ocean floor the cable breaks were 290 km apart, indicating the width of the current.

Kuenen (1952) computed the size of the turbidity current and the amount of sediments involved and predicted it might cover an area of 100,000 sq. mi.

and average about 1 m in thickness. He also pointed out that this is by no means the upper limit in size in nature and that a "multiple of area and thickness must be possible." Kuenen also assumed that the original slide was caused by an earth shock. In the beginning, Heezen and Ewing (1952, p. 869) had made up their minds "that the Grand Banks earthquake triggered off a very large turbidity current" and were "convinced of the great importance of the earthquake triggering effect."

Actually, sedimentary deposition on the continental shelf, at the mouth of the Laurentian Channel, caused excessive loading which exceeded the elastic limit of the sediments, causing sudden rupture, which caused both the landslide and the earth shock. A large segment of the sea floor, 225 km across and 100 km downslope, became unstable and let go. The large-scale submarine landslide which resulted, caused all the cables in the vicinity to snap, simulanteously. Due to the water-soaked quick-clay nature of the deposits, the avalanche suddenly changed from a solid into a rapidly flowing liquid, or density current, known now as a turbidity current. This was very ably shown by Kerr (1963) (see Fig. 1). Kerr (1963, p. 140-42) also discusses and illustrates the Grand Banks slump. Surprisingly, he states that "An earthquake triggered the slide."

The key points in this discussion are: 1) Landslides are caused by overloading, exceeding the elastic limit of the underlying material, 2) The rupture caused an earthquake with a magnitude of 7.2, 3) The epicentre is directly opposite the Laurentian Channel, in the middle of the avalanche area between 1000-2000 fathoms, 4) The focal depth of the shock was shallow - a near surface event, and 5) Rupture was followed by a major gravity slump and simultaneous failure of cables in the avalanche area, initiating a large turbidity current, that resulted in the widespread failure of submarine telegraph cables in its path over a 13h 17 min period, and generated the devastating tsunami that struck the south coast of Newfoundland, 250 km north of the epicentre, 2½ hours later, with the loss of 27 lives (Stevens, 1977). Cables north of the slump area on the continental shelf were undisturbed.

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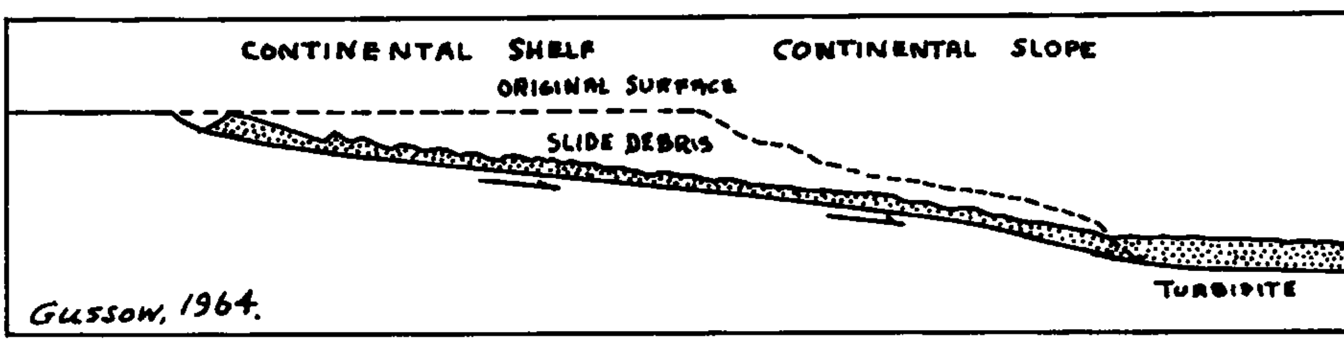

Figure 1 *A typical natural-scale cross section of the Grand Banks slump, south of Newfoundland. Adapted from Kerr (1963, p. 138).*