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Autor: Gretener, P.E.
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The plane of superweakness as a temporary condition in geology

Geological Note

by P.E. GRETENER[1]

with 2 figures

Overthrust structures after more than 100 years of study still attract a great deal of attention. There seem to be two particular reasons for this phenomenon:

a) the spectacular outcrops in mountain chains around the world give undeniable and observable evidence of large rock packages moving laterally over long distances in an almost undistorted fashion, and
b) the associated mechanical enigma of easy gliding referred to as the «basal lubrication» by early investigators.

The latter remains unsolved despite a number of hypotheses that have been developed in recent years. HUBBERT and RUBEY (1959) in their classic paper provided a new stimulus and in their wake a large number of papers on the subject have been published over the past three decades.

Some years ago (GRETENER, 1972) I showed that for easy sliding on a plane both cohesion and normal stress must be low. Only under such conditions of negligible cohesion and small normal stress can overthrust plates be moved over long distances with virtually no internal deformation. I postulated what I called the «plane of superweakness». Such a plane would exist in a shale, where the cohesive resistance to horizontal shear is minimal, and which is subject to high excess fluid pressure reducing or eliminating the effective overburden stress (**Figure 1**). However, unless the geopressure condition is confined to the particular horizon, the layers above and below will also be severely weakened, which in turn should lead to a broad zone of deformation rather than the observed, sharp gliding planes. At the time of publication this suggestion of sharply localized geopressures may have seemed far-fetched to some of the readers. It is the purpose of this short note to demonstrate that in the light of more recent evidence it is possible to build a reasonable scenario for the occurrence of such planes.

At the time of writing the earlier paper (GRETENER, 1972) rapid loading was about the sole process recognized for generating excess fluid pressures. We have come a long way since then and now acknowledge a number of processes as viable mechanisms for creating higher than normal fluid pressures (GRETENER and FENG, 1985). In particular we have come to accept the kerogen transformation as an efficient pore pressure generating mechanism. As a source rock moves through the oil window into the con-

1) Department of Geology and Geophysics, University of Calgary, Calgary, AB, T2N 1N4, Canada

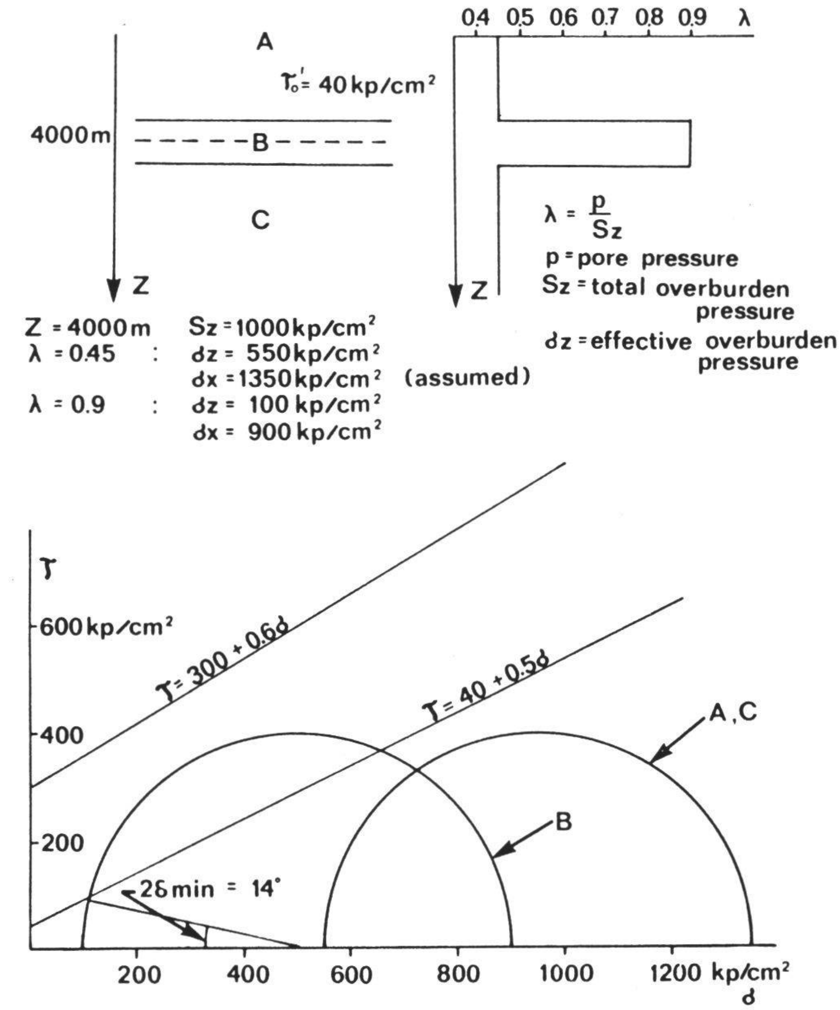

Figure 1 The concept of the plane of superweakness as proposed by GRETENER (from GRETENER, 1972)

densate and gas generating temperatures realms, overpressures are produced. The burial depth required for the onset of intense oil generation covers quite a range due to the variability of the geothermal gradient. It may be placed at roughly 2,500 m (8,000 ft) to 4,500 m (15,000 ft). MEISSNER (1978) has shown that the black shale of the Bakken Formation (a rich source rock) in the Williston Basin is strongly overpressured in the depth range where oil generation is intense (3,000+ m; 10,000+ ft). The overpressure is confined to the shale and shows as a sharp spike on the pressure-depth curve (**Figure 2**). It is now accepted that rich source rocks may be highly overpressured during intense oil/gas generation and in fact this is viewed as the driving mechanism for primary oil migration (DU ROUCHET, 1981).

We may conclude that formations such as the black shales of the Exshaw and Fernie Formations in the Southern Canadian Rockies were at one time good candidates for planes of superweakness. The Fernie shale is recognized as a major detachment horizon (DAHLSTROM, 1970, p. 344, Fig. 9) whereas for the Exshaw shale no such evidence has been produced to this date.

However, the overpressuring due to kerogen transformation is obviously a temporary situation, and after the main oil/gas generation ceases, excess pressure is likely to dissipate. An estimate of the residence time in the oil window under conditions of

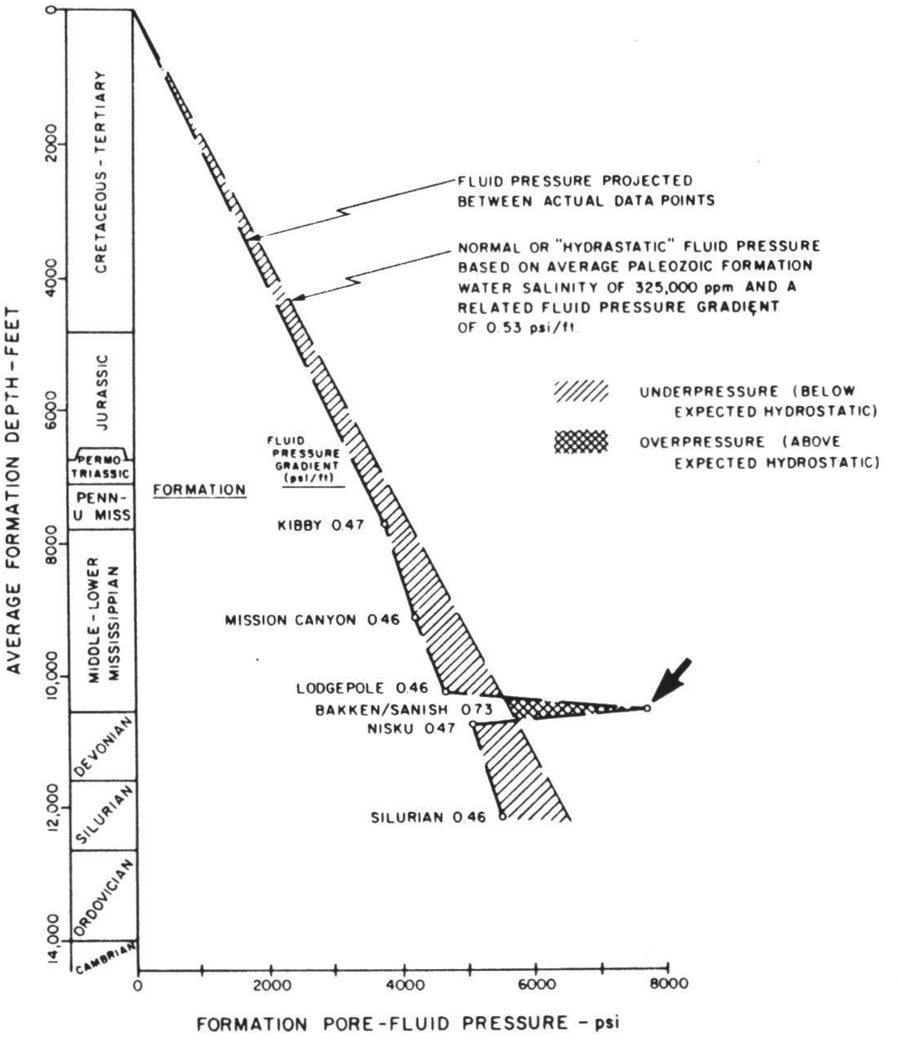

Figure 2
The sharply confined geopressure in the Bakken Formation as shown by MEISSNER (from MEISSNER, 1978).

continuos burial is found in the short communication on organic maturation following this note (GRETENER, 1989). Obviously timing is going to be an important factor. To leave a tangible, observable record the condition of superweakness must coincide with a tectonic pulse. The Bakken in the Williston Basin is unlikely to assist or trigger any deformation in this non-tectonic area.

One reviewer pointed out that the discussion in the previous two paragraphs could be construed to imply that the Fernie shales were in the state of intense oil generation during the Laramide deformation while this was not the case for the Exshaw shale. However, such a conclusion is not warranted at this time, and assembling the missing evidence — a major undertaking — is not the purpose of this short note.

Both geopressures and tectonic forces must exist simultaneously in order for this scenario to be plausible. This required coincidence also lends credibility to the episodic nature of most natural processes, another point raised in my earlier paper (GRETENER, 1972, p. 605, Fig. 16).

It is not my intention in this note to claim that most major thrusts have slid on rich source rock beds. This is certainly not the case and a yet different scenario remains to be developed. The present argument, combining GRETENER (1972) and MEISSNER (1978) does, however, demonstrate that the concept of the plane of superweakness is not strictly an academic fiction but that it can at least in principle be reconciled with observable geological conditions. It also reminds us that most geological processes are episodic and most often action depends on the coincidence between two or more events. When such events are «in phase» (AGER, 1976, p. 154, Fig. 3) «things happen» in geology and leave us often puzzling over the apparently incongruous field evidence.

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