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VI.5 Structural Complexities in Ancient Mountain Ranges

Lg propagation efficiency in Central Asia is apparently strongly path dependent and thus not easily related to gross tectonic features. However, such effects must have a structural origin and thus imply the preservation over a considerable period of time of small-scale imprints of past tectonic processes. In order to actually map such heterogeneities high-frequency data are needed, preferably of the seismic profiling type. Although we do not have access to such observations from parts of Central Asia, data from a refraction/wide angle reflection profile across parts of the Caledonides of western Norway (Mykkeltveit, 1980) will in the following be used to illustrate the potential tectonic complexities of plate collision manifestations like mountain ranges.

The refraction/wide angle reflection seismic profiling line is indicated on the map of Fig. VI.5.1, together with the two shot point locations I and II. Five 3-component seismometers were moved along the profile using an interspacing of 2.5 km on the average, while charges in the range 25-300 kg of explosives were fired at water depths of approx. 20 m at the shot points. Altogether 145 seismic field records were obtained, but many of them were not appropriate for detailed digital analysis. Many records of poorer quality, however, were used for extracting first arrival travel times.

After the necessary elevation corrections, etc., had been introduced, a Herglotz-Weichert inversion procedure was applied to the first arrival observations (see Fig. VI.5.2a). The continuously increasing velocity distribution obtained (Fig. VI.5.2b) was truncated at 12-14 km depth because the pronounced offset in the Fig. VI.5.2a travel time curves suggests the existence of a low velocity zone (LVZ) in the upper crust. It should be added that strong lateral inhomogeneity effects are ruled out when detailed comparison of records from the 2 shot points is undertaken.

The outstanding feature of the velocity model obtained is the roughly 4 km thick low velocity zone in the upper crust. Being aware of objections to such a feature on the grounds of both realistic heat generation mechanisms and limited resolving power of the data at hand, extensive synthetic seismogram analyses were undertaken. These experiments demonstrated that the appropriate model for reconciling discontinuous travel time data and amplitude distributions of primary and secondary phases in fact involved the introduction of a low velocity zone. Fig. VI.5.2c shows an extract from both the real record section (shot-point I) and a synthetic section calculated from the model in Fig. VI.5.2b, covering the distance interval over which the LVZ reflections are observed. The corresponding branches are well modelled, as seen in the synthetic section.

The nature and significance of low velocity zones are still not well understood, though the main prerequisite for such phenomena is either anomalously high temperatures and/or profound compositional changes. Within the Møre gneisses there is no evidence of high heat flow, so the postulated LVZ must be tied to velocity reversals associated with compositional changes. We note in passing that further to the north near Mo i Rana a trans-Scandinavian profile also gives evidence of upper crustal velocity reversal under the Caledonides only. In the following, two hypotheses will be examined as regards these rather unique observational data, namely, i) the Gneiss Region is allocthonous and represents an overthrust of the American block over the Eurasian, or ii) a double overthrust where serpentinized mantle/lowermost ocean crust has become 'sandwiched' between continental rocks from two opposite continents.

The geologists working with the basement/cover relations of the Caledonides in southern Norway mostly favor the view that the Møre gneisses represent an autochthonous area above which Caledonian nappes to the east have been thrust from a westerly location in the once proto-Atlantic ocean. Special support for this hypothesis is found in Råheim's (1977) work. The alternative i) above is tied to the general features of the Bergen-Namsos area which exhibits a lithologic and structural development clearly different from that of southeastern Norway. In this context, the Bergen-Namsos area may be classed as a separate Precambrian block or may represent an overthrusting part of the American block over the Eurasian one. In this case we cannot decide decisively between a serpentinite or a trench sediment origin for the Møre LVZ. However, the latter alternative seems the most attractive according to the literature on subduction tectonics. A favored mechanism imagining a

Himalaya-type doubling of the crust for the mid-Scandinavian Caledonides is illuminated in Fig. VI.5.3.

Finally, a recent Fennoscandian study supports the idea of a relatively thick crust (~ 40 km) in the coastal areas of western and particularly northern Norway as opposed to southeastern Norway (Oslofjord) with a Moho depth of around 30 km only.

The above explanations are speculative, but may on the other hand serve to illustrate that continental collision zones like the Urals and the Himalayas (in the wide sense) may exhibit localized barriers to efficient Lg propagation.

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Reference

Mykkeltveit, S. (1980): A seismic profile in southern Norway. Pure and Applied Geophysics, 118, 1308-1323.

Råheim, A. (1977): Norsk Geol. Tidsskr., 57, 193-204

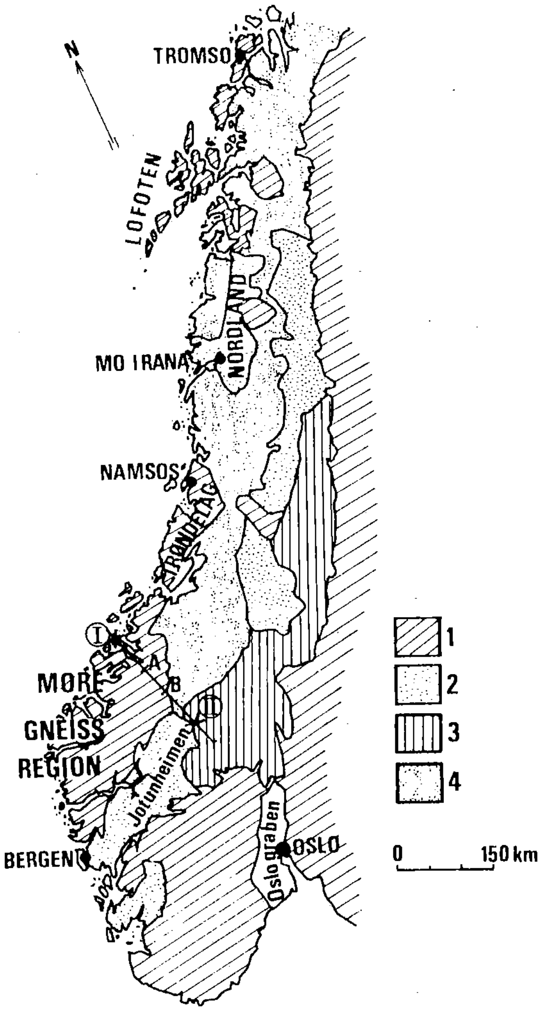

Fig. VI. 5.1 Simplified tectonic map of Norway redrawn after Reymer, including shot points I and II for the seismic profile transecting the Møre Gneiss Region. Legend markings are as follows: 1) Precambrian basement, including the generally presumed autochtonous Møre Gneiss Region, with radiometric age determinations in the range 1900-1200 Ma, 2) Mostly Precambrian nappes (1200-850 Mz) also including structures of Caledonian ages, 3) Lower Palaeozoic elements, (par)-autochtonous-allochtonous structures of mostly Cambrian-Silurian ageas, 4) Lower Palaeozoic elements, typical nappe substructures having a presumed southeastern direction of thrusting.

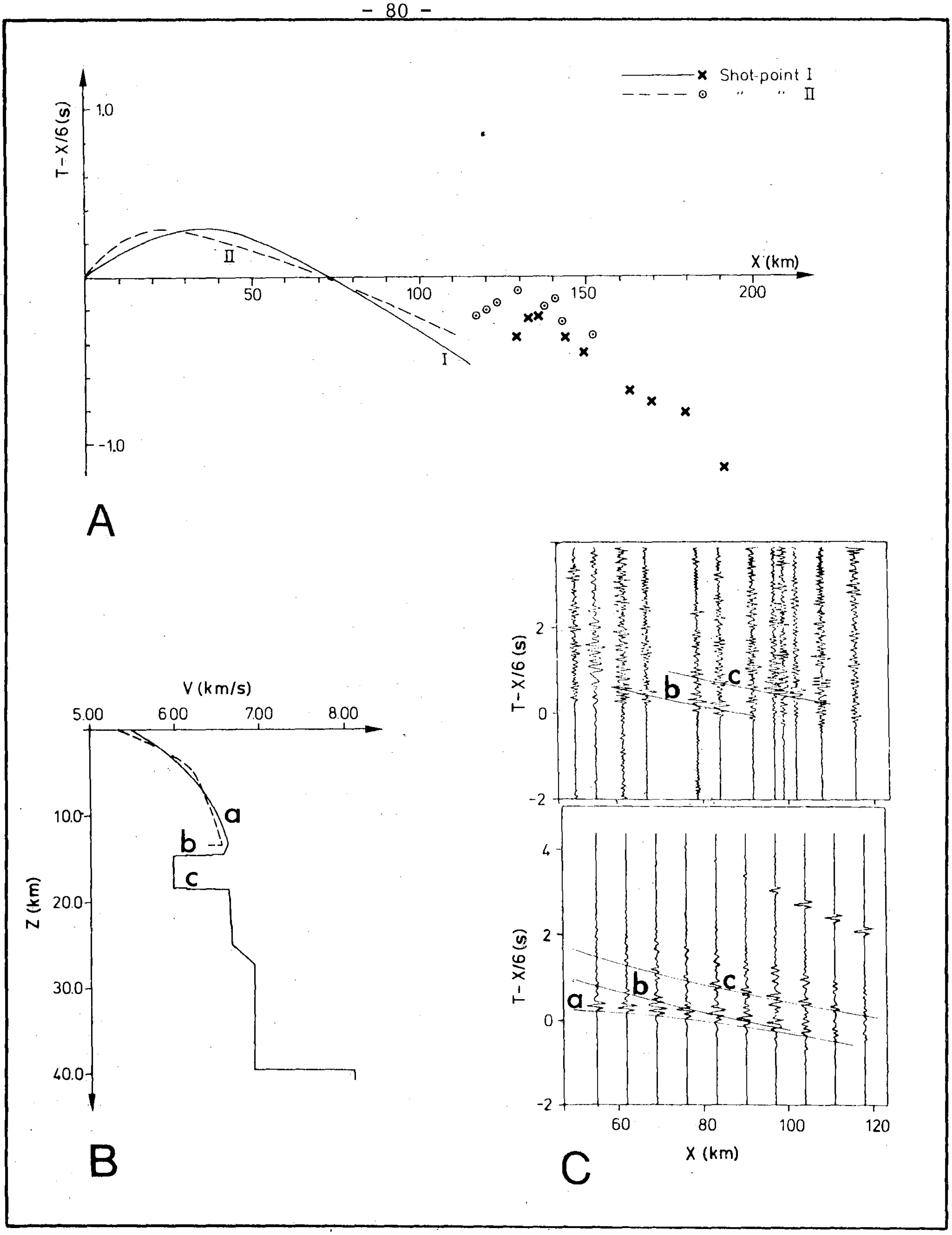

Fig. VI.5.2 A) First arrival travel times for both shot points. The continuous curves represent a slight smoothing of travel time observations. B) Velocity-depth distribution derived from shot point I data. The dashed curve corresponds to shot point II data. C) Detail of record section (top) for shot point I and corresponding synthetic section (bottom). Selected segments of the travel time curves as computed from Fig. VI.xx.2b are inserted.

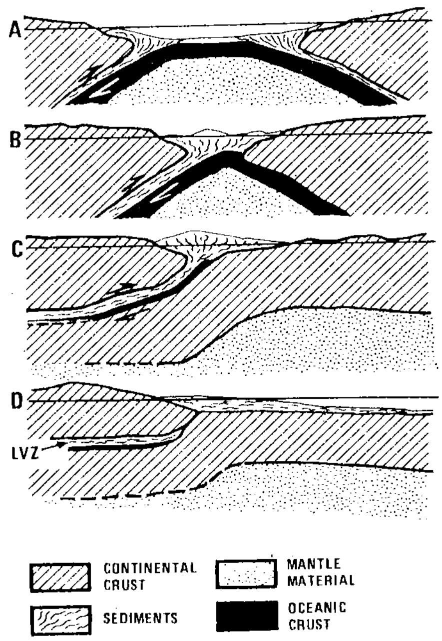

Fig. VI.5.3 Schematic and simplified cross sections of the closing of the Iapetus ocean displayed to illuminate our alternative ii) for explaining the low velocity zone (LVZ) beneath the Møre Gneiss Region. A) Late stage in the closing of the Iapetus ocean. B) Situation before the continents collide, with a westerly dipping subduction zone along which orogenic sediments are dragged down. C) The continental collision resulting in crustal doubling with sediments and remnants of oceanic crust - constituting the hypothesized LVZ - sandwiched between the two crustal blocks. D) From isostatic uplift a westerly Himalayan chain off which the nappes glide to the east.