Recent Geodynamic Evolution of Convergent Plate Margins and the Reconstruction of Fossil Plate Boundaries

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Summary: The discovery of paleoplates buried in the upper mantle leads to an interpretation of the subduction as a discontinuous process running in cycles and shifting the place of its operation in or against the direction of ocean floor spreading. This mechanism explains the distribution of calc-alkaline volcanism of different age in fossil convergent plate boundaries. The establishment of regular spatial correlation of the aseismic gap in the Wadati-Benioff zones with the distribution of calc-alkaline volcanism enables to reconstruct fossil plate boundaries and to define allochthonous terranes in apparently homogeneous continental plates. The hampering effect of the ocean floor morphology and of the fragments of continental plates approaching the trench, which substantially influences the rates of subduction and the geodynamic history of active continental margins in different domains along the trench, allows us to understand the complicated geological development of continental wedges in fossil convergent plate margins. The establishment of the segmented nature of active subduction zones and the dramatic morphology of the lower limit of the active subducted slab along the trench help us to interpret extensive lateral gaps in volcanic chains overlying active as well as fossil subduction zones.

Keywords: Plate tectonics, convergent plate margins, Wadati-Benioff zones, calc-alkaline volcanism, fossil plate boundaries

1. INTRODUCTION

Since the 1960s plate tectonics has been assumed to be the first-order geodynamic process responsible for the shaping of continents and for the creation of their internal structure. The general rules, governing plate tectonics on a global scale, have been formulated (Isacks et al., 1968) and their validity has been proved. However, the process of subduction and especially its final stage, resulting in the collision of lithospheric plates, can be essentially modified in dependence on local conditions in the individual regions.

In the last two decades we have devoted our attention to the definition of the individual stages of the subduction process and to the description of specific features of different peri-Pacific and Mediterranean regions. As the basic methodology of our investigation we have used the detailed study of the geometry of distribution of earthquake foci based on the International Seismological Centre (ISC) data and the correlation of the derived deep structure and seismotectonics of convergent plate margins with surface geology and tectonics of continental wedges overlying active subduction zones. We started with the above studies in the western margin of Mexico, Central and South America, and continued in the regions of Tonga-Kermadec, the Vanuatu Island arc, in the...
region of Kamchatka, the Kurile Islands and Hokkaido, and in the Hellenic arc (Hanuš and Vaněk, 1976, 1977-78, 1978a, 1979a, b, 1983, 1984, 1987, 1988; Vaněk et al., 1987). It should be emphasized
that seismological data define the Wadati-Benioff zone, which represents the seismically active
part of subducted slabs only. The results we have achieved in searching for the interrelations of
subduction with the geology of overlying plates and in a reasonable extrapolation of the knowledge
of recent plate tectonics into the geological past are briefly summarized in the present paper.

2. GEOMETRY OF DISTRIBUTION OF DEEP EARTHQUAKES IN THE UPPER MANTLE

The occurrence of deep earthquakes, which cannot be geometrically co-ordinated to
recent subduction zones, is a characteristic feature of convergent plate margins. This is
one of the most striking phenomena, the explanation of which seems to contribute
essentially to the knowledge of the subduction process in time. These earthquakes,
occurring deep in the upper mantle, are genetically related to the geodynamic evolution
of the respective convergent plate margin. Their occurrence seems to represent some
relics of the plate tectonic history of the region. A detailed analysis of their distribution
has been applied as the first approach to the elucidation of the causes of their origin. The
investigation of the geometry of distribution of deep earthquakes, lying outside the
contours of the active Wadati-Benioff zone representing present subductions, if studied in
a dense system of vertical sections parallel to the direction of the respective ocean floor
spreading, resulted in defining the following different patterns:

1. Deep earthquakes occur as groups of deep shocks in the upper mantle, without any
genermetrical affinity to the recently subducting slab, see Fig. 1 and (Hanuš and Vaněk,
2. Deep earthquakes are accumulated in clusters which show a tendency to form plate-
like bodies subparallel to the Wadati-Benioff zone (Fig. 2). They can either underlie
(Fig. 3) or overlie (Fig. 4) the recently downgoing slab.
3. Deep earthquakes are accumulated in irregular clusters in the immediate vicinity of
the lower tip of the Wadati-Benioff zone, broadening the lower part of the subducted
slab, see Fig. 5 and (Hanuš and Vaněk, 1978b, 1981).

The most plausible explanation of the above three patterns of deep earthquakes lying
outside the limits of the presently subducting slabs, seems to be as follows:

ad 1. The deep earthquakes distributed in the upper mantle indicate the existence of
an activated paleoslab, which displays a different orientation to that of the recently
downgoing slab. In the vertical sections, constructed in the direction of the recent
subduction, a paleoslab of a different orientation cannot be visualized as a plate-like
body. The interpretation of such a distribution of deep seismicity in the upper mantle as a
product of an activated paleoplate, belonging to a differently oriented system of ocean
floor spreading, can be proved by appropriate vertical sections perpendicular to the axis
of the respective spreading centre. As an example of this case is the Horne
paleosubduction zone in the region of Tonga-Lau, see Fig. 6 and (Hanuš and Vaněk,
1979c, 1981). The treatment of these earthquakes in systems of differently oriented
vertical sections leads to the conclusion that all deep earthquakes randomly scattered in
the upper mantle can be attributed to buried lithospheric plates. These paleoplates seem