

TECTONIC SHIFT OF OPHIOLITES AND ACCRETIONARY PRISMS<sup>1</sup>N. A. BOGDANOV<sup>2</sup>

## ABSTRACT

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The mechanism of emplacement of ophiolites in recent and pre-Mesozoic mountain chains is different and depends on their occurrence in Pacific-type fold belts or intercontinental orogenies. A correlation can be made between spreading events in the Cretaceous and periods of increased tectonic activity on continents.

Almost twenty years ago H. H. HESS revived the interest in Steinmann's ophiolite trinity, putting forward a hypothesis that they are formed due to spreading in the axial part of mid-oceanic ridges (HESS, 1965). This hypothesis, on the basis of detailed geological and petrological investigations, by geoscientists of many countries and continents has been confirmed (COLEMAN, 1977). Yet, it is still a matter of discussion how ophiolites, after having been formed in spreading oceans and representing fragments of old oceanic crust, accreted to the edges of ancient cratons, or became involved in more modern mountain chains of late Precambrian (Egypt, Sudan, Marocco) to Cainozoic (Koryak area, Philippines, Indonesia) age.

In 1968-1971 a number of scientists (DEN TEX, 1969, PEIVE, 1969) simultaneously put forward the idea, that ophiolite blocks had been obducted over an active continental margin during subduction. GANSSER (1974) emphasized that along

sutures that separate continental blocks, as for instance, in the Tethys belt, ophiolites make up a serpentinite melange, whereas elsewhere ophiolites occur as separate tectonic sheets with ultrabasites, gabbroids, dykes and basalts which vary in plasticity and density.

Such sheets are also typical for the majority of Palaeozoic fold belts of Europe – the Hesperic massif in the Iberian peninsula (DEN TEX, 1981), the massif of the Souths Urals, Minor Asia and of the Himalayas. The oceanic crust in these regions has been formed either in narrow rifts or in the Tethys ocean and a considerable part is now submerged under continental lithosphere. In fold belts, along the edges of continental blocks, only small fragments of older oceanic crust have survived.

It should be noted again that in these zones members of the ophiolite association are metamorphosed under high pressure and low temperature conditions. The general structure of these ophiolite zones is in principle applicable to the majority of intercontinental fold belts (Fig. 1).

Another mechanism for the formation of ophiolite sheets is typical for continental margins. During the Mesozoic and Cainozoic it occurred in many active zones in the Pacific, the Mediterranean and in Oman; in the Lower Palaeozoic along

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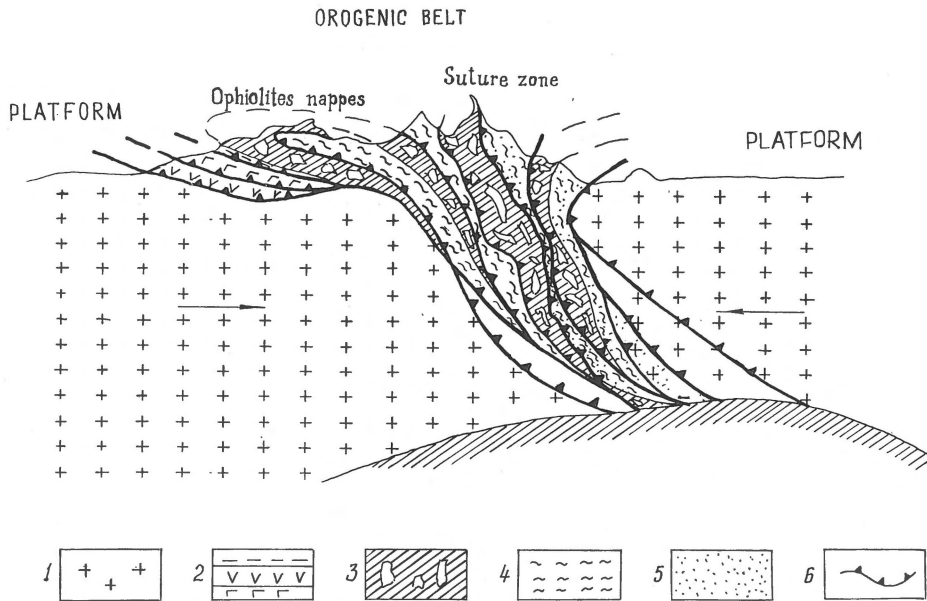


Fig. 1

Schematic cross section of idealized orogenic belt between two continental plates – Urals type (not to scale).

1 - continental crust; 2 - ophiolite association sections; 3 - serpentinite melange; 4 - folded volcanic and sedimentary rocks; 5 - metamorphic rocks of high pressure and low temperature; 6 - thrusts.

the margins of the Iapetus ocean in Newfoundland and Norway. Here the ophiolite piles are rather thick and represent complete sections of the association. An explanation for the different structures of continental margins is not necessarily related to their presence in accretion prisms of the Pacific and Mediterranean region (Cyprus, Ligurian Alps). In Oman the tectonic structure of the ophiolite section is similar, although an accretion prism is absent, or its fragments are completely thrust over the edge of the Precambrian platform. It would seem more logical to see the cause of the formation of such structural forms in relation with ocean floor spreading velocities and the direction of continental movement with respect to the mid-ocean ridge. A number of examples prove that the process itself does not depend on the size of the ocean basin, as the oceanic crust sheets are obducted over the continental margin of the Tyrrhenian Sea and the Gulf of Aden as well as the Pacific ocean.

Continental ophiolites in foldbelts are older than the formation of island arcs and flysch strata. Thus for the Caledonian belts their age is usually defined as Late Cambrian; for the Variscan Lower Ordovician, for the Alpine chain Upper Jurassic and Lower Cretaceous. The present oceanic crust was for a large part formed during the Upper Cretaceous. For this geological epoch spreading velocities and the location of mid-ocean ridges are known.

So, let us consider the formation of ophiolite sheets along continental margins of the Pacific.

Cretaceous oceanic crust makes up more than a half of the Pacific ocean floor, occupying the whole of its western and central part. The largest areas of the Upper Cretaceous oceanic crust originated between magnetic anomalies M-1 and M-0, M-0 and 30, 28 and 25 the ages of which correspond to Aptian-Albian, Cenomanian-Turonian and Maastrichtian-Palaeocene. With radiogeochronology these periods are dated 110-105, 98-85 and 65-60 Ma and coincide with the main phase of the Alpine orogeny of the continents, the Austrian, Sub-Hercynian and Laramian phases. In other words, spreading activity in mid-oceanic ridges corresponds to the epochs of intensive tectonic movements on the continents and caused a number of geological events, characteristic of that time.

Oceanic regressions, interruption of carbonate sedimentation, significant climatic anomalies, formation of volcanic plateaus and mountains in the centre of the Pacific, a shift of ophiolites to the edges of continents – all these phenomena coincide with that epoch.

The reason for the simultaneous occurrence of events, so important for oceanic geology, is in my opinion first of all the impulsive and uneven character of spreading. The study of oceanic crust, along the axial zone of the mid-ocean ridge as well as beyond, shows that melting of basalts occurred in different magmatic chambers, a fact also proved by differences in chemical composition of ophiolites in fold belts. One may state that dozens of magma chambers, primarily formed at different depths exist along the oceanic rift. At least every

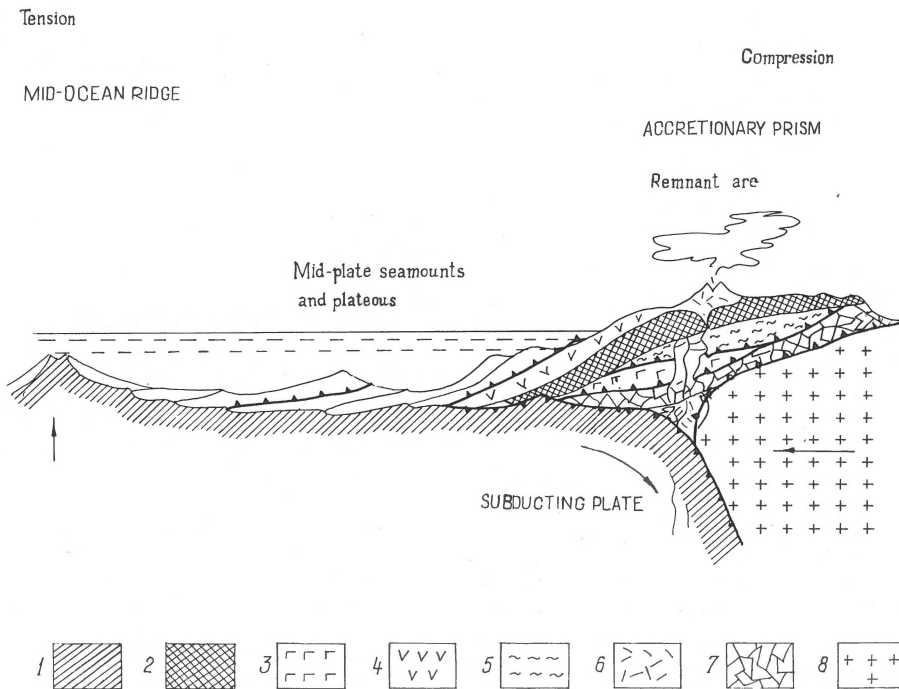


Fig. 2

Cartoon diagram showing the obduction of oceanic crust and the formation of an accretionary prism along the continental edge – Pacific type (not to scale).

1 - low layers of oceanic crust and upper mantle; 2 - complete section of ophiolite nappes; 3 - gabbroids and sheeted dykes; 4 - tholeiites; 5 - metamorphic rocks of high temperatures; 6 - volcanoclastics; 7 - olistostromes; 8 - continental crust.

segment of median valley in between transform faults has its own magma source and its specific features, although these are sometimes insignificant. Basalt effusions along the rift valley of the ridge are intermittent, although in geological time they look continuous. The same impulses are typical for spreading. They generate inclined faults and, due to non-uniformity of plate motion velocities, the formation of tectonic sheets (BOGDANOV, 1980). The rocks near the magmatic chamber axis have a high temperature (at least up to 800°C) and show weakly developed contact-metamorphism in amphibolite facies (GHENT & STOUT, 1981). It would be logical to suppose that the higher the spreading velocity, the higher the possibility of tectonic sheet formation. Therefore, in Aptian, Cenomanian and Maastrichtian times such sheets were widely produced. It is incorrect to state that all undersea volcanic uplifts and mountains from the Bikini islands to the Shatski uplift in the west to the Emperor seamounts and the Christmas archipelago in the east have a sheet structure for basement or a double section of oceanic crust. Probably, some of them have been formed as a result of normal volcanic processes. But the fact that they have been formed within the timespan of 110-65 Ma is undoubtable.

Geological sections of oceanic sheets, fragments of which have been shifted later to the edge of continents or preserved

in accretionary prisms (see Fig. 2) are characterized by the following features:

The basement of such sheets usually is an olistostrome (KNIPPER, 1978) that consists of oceanic rocks. Mostly oceanic silts into which, as a result of landslides and earthquakes, blocks of ophiolite associations and older fragments have been deposited, served as the matrix for the olistostromes (PEIVE, 1980). The Havasina series in the basement of the Samail sheet in Oman (HOPSON ET AL., 1981), the olistostromes of the South Koriak, Eastern Japan and the Southern island of New Zealand (BOGDANOV & TORCHIGINA, 1983) may serve as classical examples of such olistostromes. Usually, contact metamorphism may be traced in the basement of ultrabasites above the olistostromes. In these sections olistostromes occupy the structural place of melanges. Within vast accretionary prisms olistostromes are widespread. For instance, the Franciscan formation in California can undoubtedly be compared with a giant olistostrome in which a regular strict sequence is not observed.

The second characteristic feature of accretionary prism ophiolites is the relatively weak disturbance. It can be explained by the fact that ophiolite piles move to the continental edges as passive bodies below the subduction zone, covering the continental margin deposits of the same or younger

age. UYEDA (1983) studying subduction zones, subdivided them into two types, of low and high stress. Under high stress conditions accretionary prisms are formed in front of the continents due to landslides of continental margin rocks (Chilean type); under low stress conditions accretionary prisms in front of the continent are formed at the expense of oceanic crust (Marianas type). Ophiolite sheets, as stated above, are characteristic for the second type.

Thus, summing up this short article we may say that judging by the character of their motion over the continental crust there are two types of ophiolite sheets – continental plate collision or Ural type, and ophiolites of accretionary prisms or Pacific type. Their main difference is that in the case of the first type an envelope of tectonic sheets appeared as a result of collision of continental plates, while in the second this envelope appears during intensive phases of orogeny under oceanic conditions, subsequently thrust over the less deformed accretionary prism.

About 12 years ago Professor Den Tex drew a caricature where he showed the Devil as a creator of ophiolites. This picture is well known to geologists all over the world who study ophiolites. There is almost no doubt that the Devil did not play second fiddle in the tectonic movements also.

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