OCEANIZATION – GEOTHERMAL MODELS

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Tectonics, metamorphism and volcanism are generally endothermic processes and, as a consequence, the location of the energy-source which drives these processes is relevant. It can be shown rather easily, that the amount of energy produced by radioactive decay of U, Th and K is greater than the energy needed for the above-mentioned processes, and there is therefore no need to look for other sources of energy. In other words, the amount of heat consumed e.g. by tectonics is lost in the noise level of the variation of the terrestrial heat-flow. We may turn the argument around, and say that it is probably the variation in the lateral distribution of the (radiogenic) heat sources, which determines the location and timing of tectonic phenomena.

By simple calculations it can be shown that the temperature under the continents should be higher than under the oceans, if a state of thermal equilibrium were reached. Geophysical observations, however, on the average depth of the asthenosphere under the continents ($\rightarrow$ 160 km) and under the oceans ($\sim$ 80 km) show that this is not the case at the present time. We must be at present in a state of thermal disequilibrium, and the mantle under the continents is presumably heating up, while under the oceans it is cooling down. This should eventually lead to a reversal of the slope of the upper surface of the asthenosphere.

The whole system, as it moves towards thermal equilibrium, becomes gravitationally unstable, and a new cycle of continental drift will start. A very approximate calculation shows that the periodicity of this phenomenon will be of the order of a few hundred million years. The pulse of the earth seems to be caused by the fact that the radioactive elements are very unevenly distributed in the lithosphere, and it is this geochemical contrast between oceanic and continental crust which causes and perpetuates the tectonic mobility of the crust.

Apart from the megatectonic processes which in the present view are caused by the difference in heat-production between continents and oceans, there is also an interesting class of tectonic phenomena of smaller size. It has been shown that in the Mediterranean, for example, there are several ocean-type basins which must have been land-masses in the not too distant past. This disappearance of continental crust, and the formation of new ocean-type basins has been referred to as "mediterranean oceanization". It looks as if there is some relation to the alpine orogenic chain, although these phenomena postdate the main alpine folding. The accompanying figure shows in a very schematic way the main elements of the alpine fold belt in the Mediterranean area, and the location of some of these "holes". Some have already been filled with a thick series of late-Miocene to Recent sediments, whereas another "hole" (the Cyclades) is still in an early stage of formation. From a glance at this schematic picture, one gets the impression that these holes are located in those places where there is a sharp curve in the alpine chain. A model which explains the formation of the holes as

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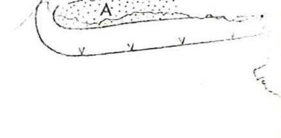

well as their preferred location in the arcuate parts of a fold chain, would be the most plausible.

The thermal consequences of a thickening of the crust, due to folding of sediments can be calculated. The temperature at the base of a continental crust of 40 km thickness will be approximately 200°C higher than at the base of a crust of 30 km thickness, if thermal equilibrium is attained. One of the consequences of such a temperature increase for a column of 100 km thickness is an expansion of the column by slightly more than 3 km and, if erosion removes this excess height the combined effects of isostasy and erosion will result in a total erosion of about 20 km. The time-scale of the process will be of the order of a few tens of million years, and therefore thermal effects will not be significant at a depth of more than 100 km.

What is described here, is essentially the thermal development under a straight mountain chain. In an arcuate fold belt the situation will be different. At the concave side of a curved fold belt, the heating effects of both segments of the arc will affect the same column, and thus tend to reinforce each other. At the convex side the situation is reversed, and the underlying column will be less heated than under a straight fold belt, because the same amount of heat is here dissipated over a larger area.

These effects together will cause the formation of a thermal "blister" at the concave side of the arc, and a more pronounced fore-deep at the convex side. There will be strong erosion from the thermal blister, as well as the formation of gravity slides from the center of the uplift into the fore-deep. There will come a time that erosion and tectonic denudation have proceeded to the stage that heating changes into cooling, and the uplift into subsidence. If erosion has been fast and thorough, a large portion of the crust may have disappeared in the mean time, and the crust may have become so thin as to resemble an ocean-type crust. The fact that erosion does not stop at the time that the crust has regained its normal thickness is due to the fact that thermal effects are transmitted slower than pressure effects. Once the heat sources have been eroded away, the process does not stop immediately because the temperature in deeper parts of the underlying mantle may still be rising.

It is therefore not surprising that the foundering stages of such thermal blisters in the convex sides of arcuate fold-belts are often accompanied by volcanism, the decompression by erosion, and the simultaneous heating of the deeper portions of the column both favouring the formation of silicate melts.

As a conclusion we may say: the cause of tectonics is in the crust, not in the mantle. This statement holds for continental drift and plate tectonics (megatectonics) as well as for basin formation and uplift (mesotectonics).

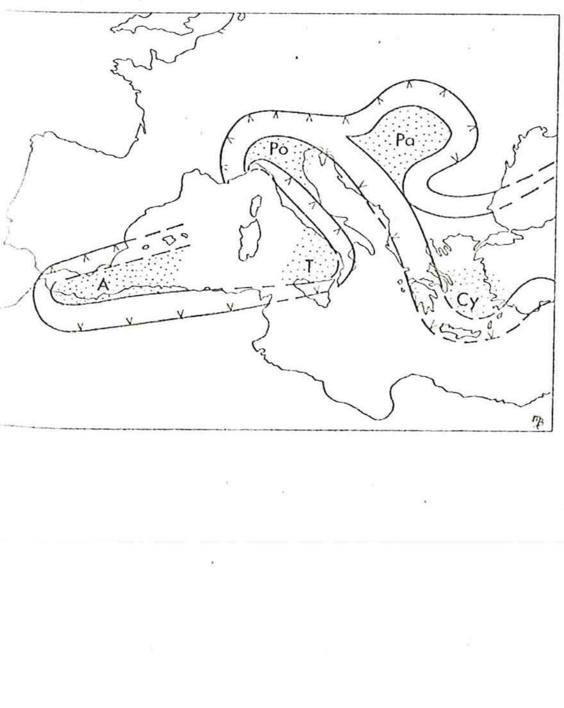

Fig. 1
Schematic outline of the alpine fold-belts in the Mediterranean area. The direction of main overthrust movement has been indicated by arrows.
Areas of Mediterranean oceanization are as follows:

A – Sea of Alboran
T – Tyrrhenian Sea
Po – Po basin
Pa – Pannonian basin
Cy – Cyclade Area

The indicated areas are located in the concave side of an arcuate part of the alpine fold-belt.