

THE UNDATATION THEORY ^{1) 2)}

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The undation theory gives a synthesis of the terrestrial evolution, uniting geological, geophysical, and geochemical data into a comprehensive model. It accepts the major views of the new global tectonics (plate tectonics) and gives full attention to the geochemical evolution of our planet (Fig. 1). In this way the undation theory strives for a complete integration of the Earth Sciences into the general spectre of the Sciences of Nature (Table 1).

This model of terrestrial evolution has been developed more or less systematically in the course of half a century (1927-1977) by means of the "prognosis-diagnosis method of verification". Available basic facts of observation have been arranged into tentative hypotheses of interrelations, and the rational consequences of that supposition are checked by independent data. This often leads to refutation of the initial ideas or to their adaption to newer knowledge. Thus the cumulative incorporation of new evidence eventually led to the present state of the undation theory.

From an initially mobilistic approach in the interpretation of the newly found overthrust structures of the Betic Cordilleras in southern Spain (Ph. D. thesis Delft, 1927) the author — influenced by the ideas of Stille (1924) and Haarmann (1930) — switched in 1931 to a fixistic attitude in the interpretation of his fieldstudies in Indonesia. His books on the geology of Indonesia (1949, 1954) were written according to fixistic principles.

In 1950, during an expedition to Iceland, he advised his pupil Jan Hospers to study the remanent magnetism of a pile of successive outflows of plateau basalts. Hospers' Ph. D. thesis on this subject with Runcorn at Cambridge (who investigated at that time remanent magnetism in sediments) initiated a new branch of geosciences, 'paleomagnetism'. This new source of diagnostic facts brought eventually convincing evidence for continental drift and sea-floor spreading, so that a search for a synthesis between fixism and mobilism became necessary (Fig. 2).

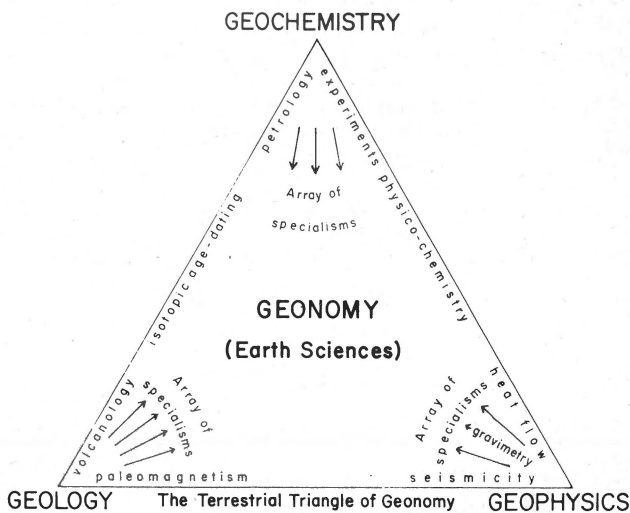


Fig. 1 The triangle of the earth sciences (geonomy) (from van Bemmelen, 1975a).

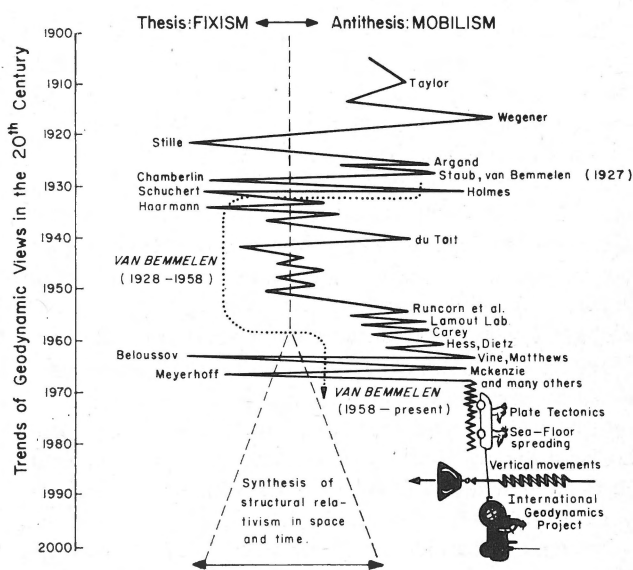


Fig. 2 Trends of geodynamic views in the twentieth century (from van Bemmelen, 1974).

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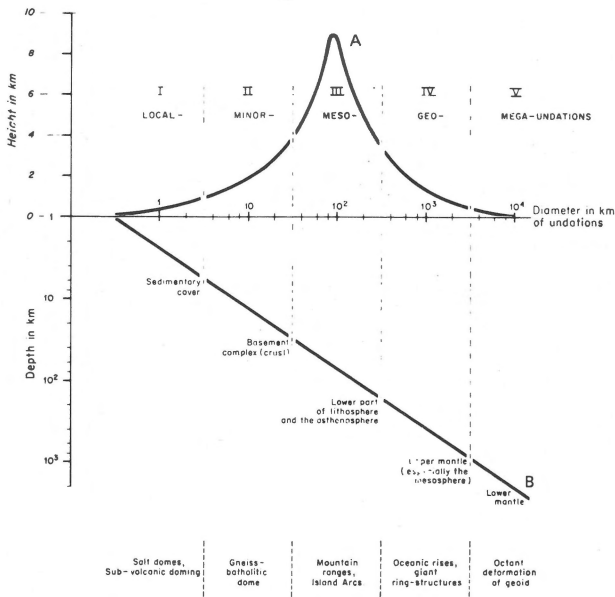


Fig. 3
Five classes of undations (from van Bemmelen, 1976).

5. The vertical movements of undations produce *potential gravitative energy* with fields of internal stresses. This leads eventually to lateral movements of masses, called '*gravity tectonics*'.

Mega-undations of global dimension result from ascending currents of the lower mantle which produce upwarps of the outer spheres. Their ascent is volumetrically compensated by subsidence of adjacent geosynclinal zones. The related stress fields may result in continental drift and the opening of ocean basins such as the Atlantic (Fig. 4).

Geo-undations of a smaller scale result from upwellings of upper-mantle matter. Operating under continental shields mantle diapirs of low velocity bodies ascend into the lithosphere and may corrode the sialic crust. The corresponding magmatic and volcanic processes can be studied in giant ringstructures and centres of diastrophism in mobile belts. Such diapirism creates tumescent crustal areas, surrounded by narrower trenches of subsidence (Fig. 5).

In their later stages of evolution these centres of diastrophism spread under gravity, compressing the marginal trenches into nappes of the Pennine type and overrunning them with nappes of the Austro-alpine type (flysch phase of Alpine orogeny).

Operating under newly formed deep oceans upwellings of upper-mantle matter create mid-oceanic rises. There is a time-lag of tens of million years between the formation of these mid-oceanic geo-undations with respect to the zenith of the evolution of the causative mega-undation. This time-interval was needed for geochemical reactions to the pressure

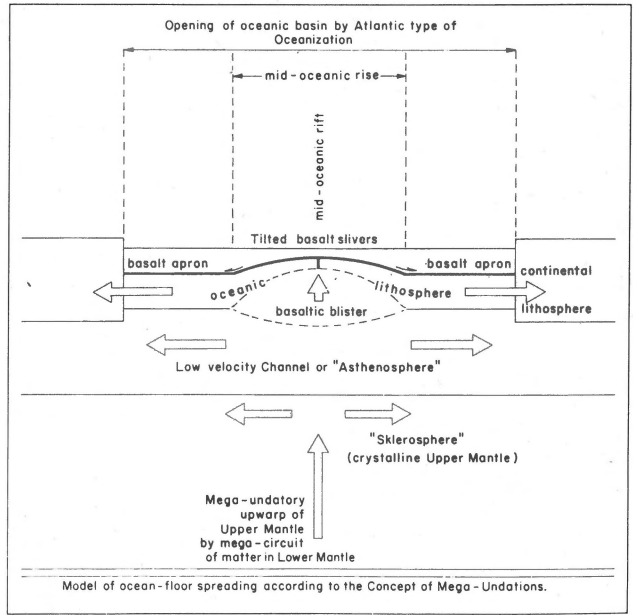


Fig. 4
Model of continental drift and sea-floor spreading by mega-undations, based on the rheological principles of gravity tectonics (from van Bemmelen, 1976).

relief in the top part of the mega-undation, which eventually resulted in the formation of buoyant blisters of anomalous upper-mantle matter, rich in eutectically segregated basaltic magma (van Bemmelen, 1976).

New oceanic crust is created by basalt outflows along the rift at the crest of the rise, and then glides from its shoulders. This type of gravity tectonics can be studied by paleomagnetism, because reversals of the magnetic field produce characteristic strips of remanent magnetism in the spreading ocean floor (see Fig. 4).

Meso-undations are represented by the mountain- and island-arcs which are pushed up from foredeep-trenches. After the gravity tectonics of the flysch phase, mentioned above, geochemical reactions to the changes of the P-and-T conditions produced intra-crustal 'asthenoliths'. It takes another time-interval of some tens of million years till these buoyant bodies push up mountain ranges, which are volumetrically compensated by the subsidence of side-deeps. This is the molasse phase of orogeny. The accompanying gravity tectonics produce décollements of the sedimentary cover, like the Helvetic nappes of the Alps, and slides of the basement complex over intra-crustal listric fault planes (Fig. 6).

Minor undations are connected with still more restricted diapirism of gneissic domes and batholiths. The resulting gravity tectonics may lead to intra-crustal mushrooming, and at the surface ignimbrites may issue from tensional rifts or volcanoes may come into being.

Local undations have their origin inside the sedimentary

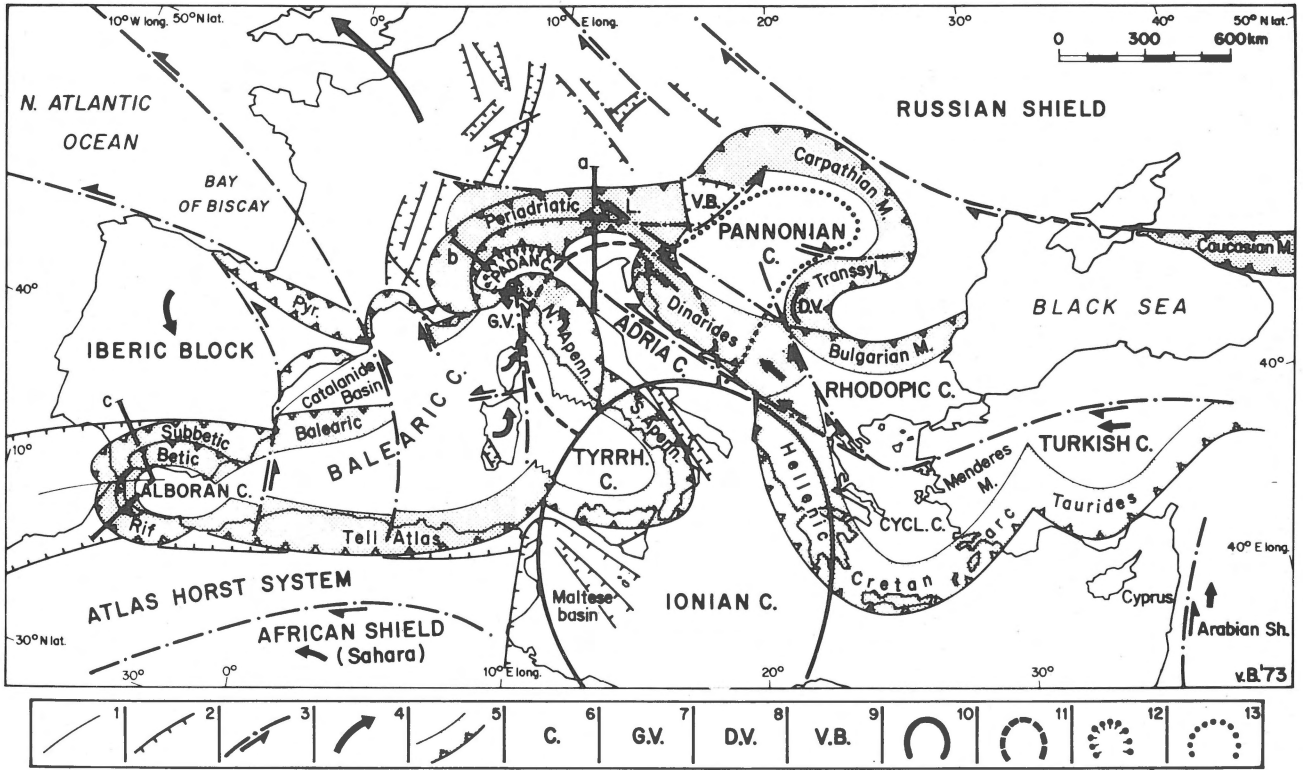


Fig. 5 Centres of diastrophism in the Mediterranean area, surrounded by mountain arcs of the Alpine system (from van Bemmelen, 1974).

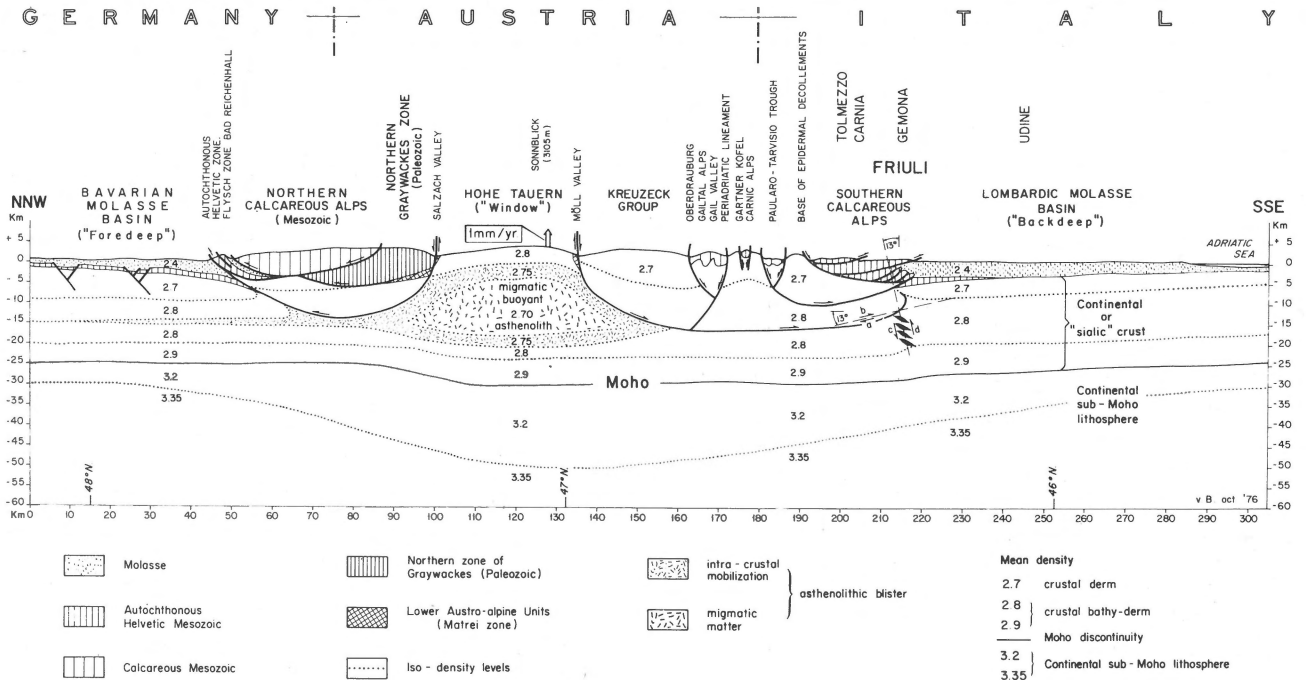


Fig. 6 Schematic section across the Alps, and its relation to the seismic activity in Friuli (NE-Italy) in 1976 (from van Bemmelen, 1977). An attentive reader may remark that his section across the Eastern Alps differs from my former sections across this sector of the Alpine orogen. The explanation is that Fig. 6 represents the *status quo*, whereas the other sections are palinspastic reconstructions of older phases of evolution in which the northward overthrusting movements prevail (e.g. Fig. 8 on p. 44 in van Bemmelen, 1973).

skin due to density inversions of the deposited strata, or they might be caused by laccolithic pockets of magma (subvolcanic chambers).

Their diapiric ascent is followed by gravity tectonics, such as mushrooming, outflows of mud, salt, lavas, and mélanges or collapses of volcanoes (see van Bemmelen, 1949, 1954).

The foregoing five points are the basic principles of the undation theory. The elaboration of this model led in the course of years to a number of characteristic special features, some of which are mentioned here-after.

6. The *cosmogony of our planetary system* has a very important bearing on the further geochemical and geodynamic evolution of the earth.

6a. The proto-earth acquired an envelope of satellitic matter, which was transformed into a world-wide primeval crust (van Bemmelen, *et al.*, 1967; van Bemmelen, 1975) (Fig. 7).

6b. The proto-earth originated by planetesimal accretion around an initial gravitational centre, formed by the agglomeration of some huge planetesimal bodies, which had different mean densities. This inhomogenic centre of accretion now forms the inner core, which could maintain its asymmetric density distribution up to the present, because it is situated in the near-zero part of the terrestrial gravity field. Consequently, the inner core reacts in a different way to the tidal forces of the earth-moon system than the remaining part of the earth. Its rotation approaches the period of the moon's orbit, whilst the period of revolution of the rest of the earth has slowed down to 24 hours. This difference of rotation velocity created a transitional zone, some 550 km thick, in which energy of rotation is transformed into heat by turbulent internal friction. This might be the fundamental source of free energy for the entire post-cosmogonic evolution of

our planet, accompanied by a geomagnetic field, gravity anomalies, seismicity and global tectonics (van Bemmelen, 1976) (Fig. 8).

7. The *deep-oceans*, characteristic of the present geodynamic and geochemical situation of the crust, are a late product of terrestrial evolution. In early pre-Cambrian times the globe was covered by extensive, rather shallow seas, less than 3000 m deep, and the crust — through thinner and more mobile than the crust of the present continental shields — had already a predominantly sialic composition. The transformation of this world-wide primeval crust into emergent continental shields with sialic basement complexes and deep oceans with a basaltic floor came to the fore in the latest phase of evolution (phase III on Fig. 7).

The mobile Tethys belt, for instance, was underlain up to Permo-Triassic time by a sialic basement complex which subsided epeiro-genically under shallow seas. Neither the early Tethys, nor the Neo-Tethys (which formed during Jurassic and early Cretaceous time) was an embayment of 'Panthalassa', the hypothetical proto-ocean around Wegener's reconstruction of 'Pangea' for the distribution of land and sea at the end of the Paleozoic.

8. The transformation of areas with a sialic crust into oceans with a simatic (basaltic) crust can be accomplished by two different processes of 'oceanization'.

8a. The *Atlantic type* of oceanization is a mechanical process, namely the drifting apart of continental shields (see Fig. 4).

8b. The *Mediterranean type* of oceanization is a geochemical process, namely corrosion of the sialic crust by convection currents in the upper mantle, such as rising diapirs of the asthenosphere (van Bemmelen, 1972 a, b; 1973), or the spreading out of mega-convection circuits in the mantle moving along the base of the sialic crust (van Bemmelen, 1976).

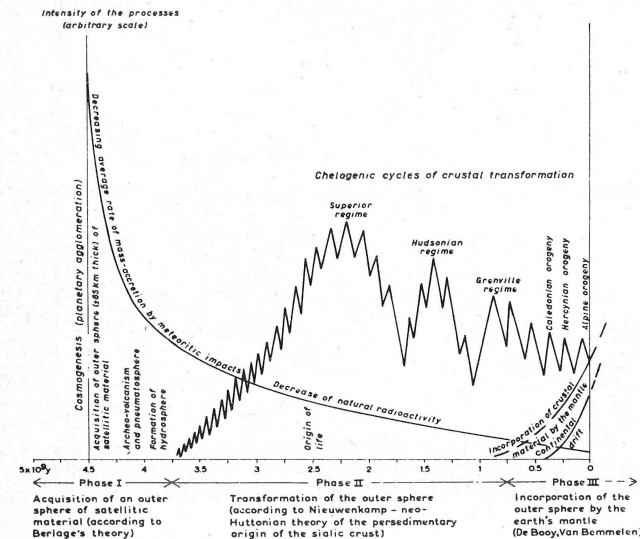


Fig. 7 Non-uniformitarian phases of crustal evolution (from van Bemmelen et al., 1967).

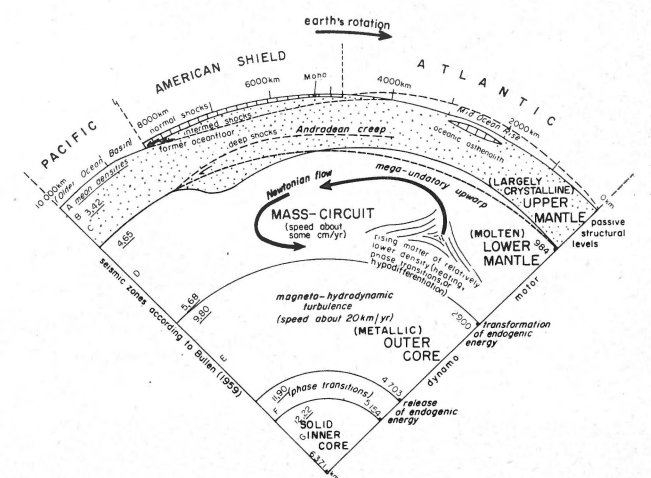


Fig. 8 Step-wise flow of endogenic energy from the inner core to the global surface. The transition zone between inner and outer core might be the result of transformation of rotative energy of the earth-moon system into frictional heat of turbulence (from van Bemmelen, 1972a).

9. *Ophiolites* are not the product of transformation of the basaltic crust of pre-existing deep oceans. They are related to orogenic processes, being emplaced in the ensialic environment of the marginal trenches of centres of diastrophism. Even the basic to ultra-basic masses of Cyprus, Oman, New Guinea's North coast, New Caledonia, etc. are all related with initially tumescent diapirs which collapsed in their later stages of evolution, forming subsequently smaller ocean basins (see sub 5b, and van Bemmelen, 1973, fig. 21; 1974, fig. 4; 1975 a and b; 1976).

10. *Blue schists* (i.e. the glaucophane facies of high pressure low temperature metamorphism) are not formed at great depths, but originated in the same environment as the ophiolites, namely in synorogenic trenches. They owe their exceptional metamorphism to the high strain rates during the flysch phase of compression and overthrusting (van Bemmelen, 1974).

11. *Subduction* is the geodynamic process of disappearance of the oceanic lithosphere, which is accompanied by deeper centres of earthquakes (Benioff zone). Distinction should be made between active and passive subduction. The *active subduction* is connected with the quasi-steady sea-floor spreading and promoted by the increasing density by cooling of the oceanic crust during its ageing. The *passive subduction* results from the loading of the oceanic lithosphere by advancing mountain- and island-arcs, or loading by huge delta's (such as the Indus delta). Further descent is promoted by the formation of high-density mineral phases. Type localities are

the Japan Arc and the Sunda Arc of Indonesia (van Bemmelen, 1974) (Fig. 9).

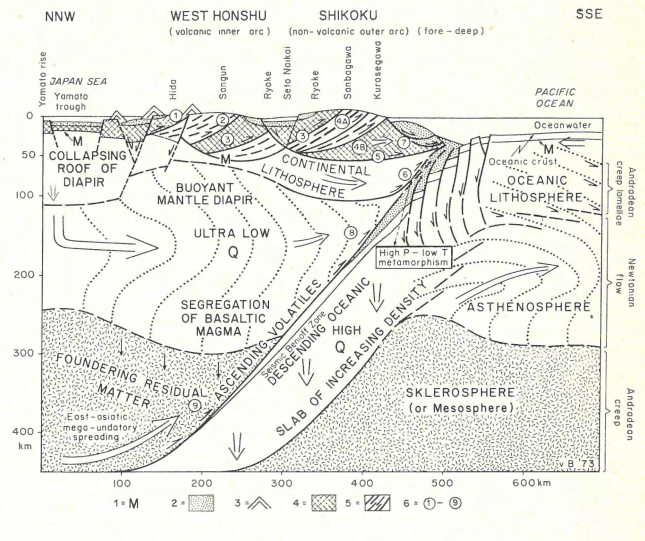


Fig. 9 Section across the Japan arc (N.B.: the upper part is not to scale) (from van Bemmelen, 1974).

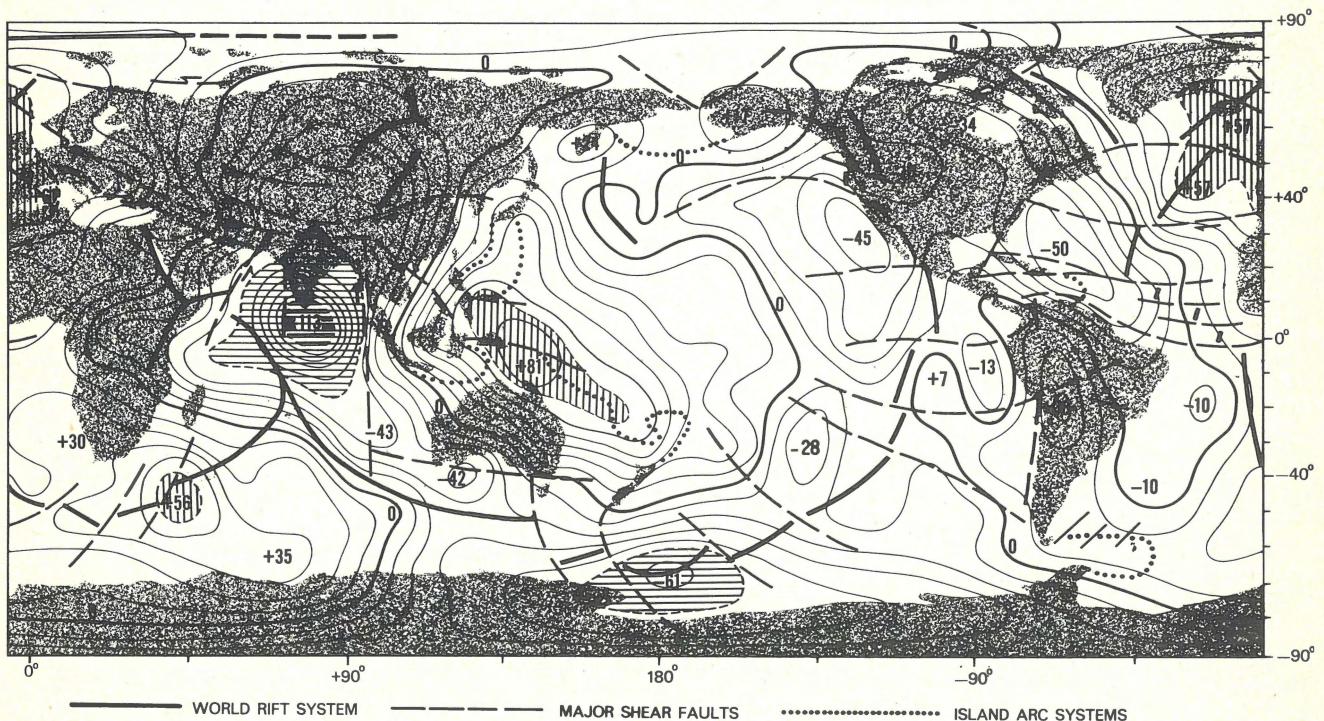


Fig. 10 Relations between major gravity anomalies of the geoid and geodynamics of the lithosphere (from van Bemmelen, 1975b; see also Hédervári, 1977 in *Tectonophysics*, 40 (3/4), p. 369 and 372-374).

12. *Obduction* is a misnomer in mechanical sense. According to the geological analyses of developments of the relief and structures (palinspastic maps and sections) neither the overthrust sheets of the Alps, nor the basic to ultra-basic nappes of Oman and New Caledonia were pushed upward. They are the result of the spreading of tumescent centres of diastrophism in their rear during the flysch phase of orogeny. Only thereafter, during the molasse phase, a general inversion of the relief occurred; namely the area of provenance collapsed, creating a smaller sea basin of the Mediterranean type, whilst the marginal trenches were pushed up into mountain and island arcs (see sub 5 and van Bemmelen, 1973, 1974).

Recently Dewey (1976, 1977) published some penetrating studies on 'ophiolite obduction' and 'suture zone complexities', which illustrate my objection. These studies do not take into account the differential vertical movements which preceded and succeeded the emplacement of high-density nappes. Whilst such a palinspastic analysis of the successive internal stress fields, created by gravitational potential, is essential for our understanding of the mechanics of emplacement.

13. The latest development of the undation theory is the insight that there is a *causative relation between the major gravity anomalies of the geoid and global geodynamic processes* (van Bemmelen, 1975 b, 1976) (Fig. 10).

This leads to a more *rheological interpretation* of geodynamic processes, such in contrast to the approach of plate tectonics, which suggests rigidity of huge lithospheric plates.

The general and special features of the undation theory represent a highly adaptive and apparently functionally correct model of the global evolution. Its expectations (prognoses) are in agreement with the great fund of basic facts of observation (diagnostic facts). It leads to new insights, new approaches of research, and it helps to predict future events of development.

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