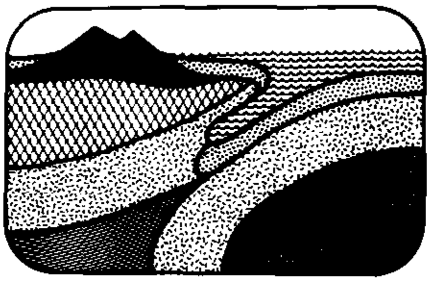

Hydrosphere and Continental Crust: Growing or Shrinking?

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Abstract
Crust is removed by the subduction of spilite not basalt. On account of the higher water and potassium content of spilites, the entire hydrosphere and continental potassium are subducted about each *billion years. If the earth is* cooling, there must be a trend to increasingly retain some fraction of such subducted surface materials in the mantle. If so, the granitic and oceanic mass, could have decreased through time.

Résumé
Les roches de la croûte océanique qui s'abîment dans les zones de subduction sont de nature spilitique et non basaltique. Etant donné que les spilites sont enrichis d'eau et de potasse, tout le contenu de potasse des continents et toute l'eau des océans pourraient entrer dans la composition du manteau en une période d'un billion d'années. De plus, si la terre est en train de refroidir, on peut prévoir qu'une fraction de plus en plus importante de matériaux sialiques sera *retenue dans le manteau.* Ainsi, selon cette hypothèse, la masse des continents et des océans aurait pu décroître avec le temps.

The steady state is foreign to any natural system. Some systems may have such large inertia that rates of change are slow and difficult to measure. It is in this sense, that comparisons of geologic processes over the greatest possible time span have such importance. In forming models of tectonic evolution, the variation of the thermal structure of the earth with time must have central importance. Evidence on this subject is tenuous. Most earth scientists believe that the earth is cooling. Certainly, almost all heat sources decay with time and it is difficult to conceive that the earth is still heating up. Geologic evidence for a cooling earth is not spectacular but nevertheless becomes *increasingly convincing.* Overall, metamorphic processes in ancient crust reflect steeper thermal gradients (lack of blue schists, lack of ecologites, presence of low-pressure granulites) while some ancient igneous processes (peridotite lavas, An_{99} anorthosites) *suggest a hotter mantle or higher* melting zones in the past. In general, Archean geology, as shown by Archean geologic maps, is one of igneous and high-temperature metamorphic events.

In the last decade we have seen the *explosive accumulation of data* supporting the ideas of plate tectonics, a convective process where new lithosphere is created and equally efficiently destroyed. The motions are fast in terms of earth history. To use John Elder's expression, the "roll-over" time of the crust is short, a few hundred million years. Elder's (1972) model of convective cooling and thermal turbulence, appears appropriate to many geologic observations concerning thermal history.

If the earth is cooling, and if the different parts of the earth are in chemical communication by convective mixing processes, it is valid to ask if the present state of the earth is stable or if there are more stable configurations that will be approached. Reflection on this question shows definitely that the present structure is not stable for a cooler earth. For example; our oxygenated atmosphere is not in *equilibrium with the mantle: our* hydrosphere would not be in equilibrium with a cooler peridotite-basalt outer shell, silica in the crust could form pyroxene in an ultramafic mantle, albite would go into pyroxene, orthoclase and water into phlogopite, etc. Our *continental crust and hydrosphere are* present simply because they represent easily fusible or volatile species which, even if subducted, are rapidly thrown back to the surface by thermal energy. Obviously, if the earth is cooling, many of *these fixation processes may be* gradually occurring, the oceans may be going back to the solid earth and granites back into the mantle. If this is happening, the overall influence on the evolution of the surface could be far reaching.

Thinking on the earth's *chemical* balance has been drastically changed by the recognition of the rates of creation and destruction of new lithosphere. In particular, the importance of the spilite-forming reactions are being recognized (Keen, 1975) and the fact that it is spilite and not basalt that is subducted. The significance of the linkage basalt-sea water-spilite-andesite has only recently been considered (Fyfe, 1975). And now, even in "textbooks", we read that sediments may be subducted on a large scale (Gilluly, Waters and Woodford, 1975, p. 136).

The deep subduction of lighter sedimentary material has always *caused conceptual problems* but all that is required is that the mean density of the cooler descending lithospheric slab is greater than the mantle through which it descends. At the recent Penrose conference on the lithosphere-asthenosphere boundary, seismic data *were presented for more eclogite in the* lithosphere than previously considered (Fuchs and Schulz, 1975); if this is correct, the volume of light material subducted may be greater than previously suspected. Further, when subduction rates and the temperatures *in a descending slab are considered,* transitions of the type: graywacke (andesitic) to dense glaucophane schist and quartz-phlogopite eclogite, make subduction of such material more probable.

To emphasize the importance of the subduction process, let us consider two species that are of particular significance to continental crust and hydrosphere, water and potassium.

New basaltic ocean floor forms at a rate of about 10 $km^3\,yr^{-1}$ and most must be subducted. The subducted ocean floor crust becomes hydrated before subduction (chlorite, epidote, serpentine, etc.) and most spilites have *about five per cent water (neglecting* pore water). Assuming that the 10 $km^3\,yr^{-1}$ is thus hydrated, the subduction rate of water is 1.5×10^{15}g yr^{-1} and the entire ocean volume would be subducted in about one billion years. We know that much water may be returned in the blueschist environment, but some may be carried to great depths to account for the general nature of andesites (Fyfe and McBirney, 1975).

Ocean ridge basalt contains potassium at low levels (ca. 0.2%). Sea water interaction not only increases sodium but potassium as well. The average spilite has more like one per cent K_2O (Hyndman, 1972; Keen, 1975).

Thus, the potassium subduction rate could be as great as 3×10^{14}g yr^{-1}. If the continental crust averages two per cent potassium, then as the continental crust has a mass of 1.6×10^{25}g, all this potassium could be subducted in a billion years.

Such figures for potassium are probably too large, but the trends are real. In addition the contribution from subducted sediments may be large. If the earth is cooling the hydrosphere and potassium content of the crust must decrease. And the present rates are not trivial in relation to geologic time.

The consequences of such a phenomenon are far reaching to every part of geology, both inorganic and biological. There would be more, but probably thinner, continental granitic crust in the Archean; the oceans might be deeper and more extensive. There is much to support such a concept in the geologic maps of the ancient remnants. Variation in the massive exchange process could change the chemistry of sea water, particularly the alkali metal ratios and carbon dioxide content. If the above is true for H_2O and K, it will also apply to many other volatile and sialic elements and implies that the overall differentiation of crust and mantle may have been more perfect in the past than the present.

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