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HOT SPOT ABUNDANCE, RIDGE SUBDUCTION AND THE EVOLUTION OF GREENSTONE BELTS

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A number of plate tectonic hypotheses have been proposed to explain the origin of Archaean and Phanerozoic greenstone/ophiolite terranes. In these models, ophiolites or greenstone belts represent the remnants of one or more of the following: island arcs (1,2), rifted continental margins (3), oceanic crustal sections (1,4), and hot spot volcanic products (1,3,5). If plate tectonics has been active since the creation of the earth, it is logical to suppose that the same types of tectonic processes which form present day ophiolites also formed Archaean greenstone belts. However, the relative importance of the various tectonic processes may well have been different.

The Archaean earth is postulated to have had greater internal heat production and consequently a younger maximum age of the oceanic lithosphere at subduction (6,7). One of the consequences of a greater proportion of subduction of young oceanic lithosphere in the Archaean is that ridge subduction would have been more common (7). The most common type of ridge subduction in the Archaean would have been that where oceanic lithosphere comprised both the overriding and subducting plate. The only present day example of this type of subduction is the subducting ridge in the Woodlark basin. This ridge crest has several geochemical anomalies: basalts with an island arc signature, and a dacite volcano on the ridge crest (8,9). The island arc component of the basalts has two proposed origins: contamination by an older subducting plate due to polarity reversal of the arc (9) and fluid contamination from the base of the subducting plate (10). Plate reorganization and ridge subduction are both postulated to have been more abundant in the Archaean (7). Regardless of the mechanism by which the arc-like component is generated, Archaean oceanic crust emplaced on land would have been much more likely to have an arc-like composition. Similarly, the dacite volcano observed on the Woodlark basin ridge crest could also have counterparts in Archaean greenstone belts.

Other aspects of the Woodlark basin subduction system may also have relevance for Archaean greenstone belts. The New Georgia island arc, which is being formed by subduction of the oceanic crust of the Woodlark basin (Figure 1), is composed of overlapping volcanoes, located 4-70 km above the Benioff zone (11,12). The New Georgia arc is quite different from a 'typical' Phanerozoic arc, e.g. the Marianas arc (Figure 2). In the Marianas, the volcanoes are spaced 50-100 km apart and sit 125-150 km above the Benioff zone (13,14). The island arc volcanics of the New Georgia arc also have some unusual characteristics. One island is a picritic volcano, thought to be the direct result of the ridge subduction process (8). If a higher percentage of Archaean island arcs were like the New Georgia islands, individual volcanoes would possess overlapping edifices and picritic volcanoes would occasionally occur. The overlapping volcanic edifices would increase the thickness of layer 2 (the pillow basalt layer) and would increase the probability of multiple phases of hydrothermal activity. Consequently, the relative abundance of Archaean ore deposits could be due to the greater incidence of New Georgia-like island arcs.

Another probable consequence of greater internal heat production in the Archaean would have been a greater abundance of hot spot activity. For example, in the Phanerozoic, global ridge volume in the Cretaceous is thought to have increased and to have caused the Cretaceous sea-level high. This increase in the global sea floor creation rate may have coincided with an increase in hot spot activity (15). If increases in hot spot activity do coincide with increases in sea floor creation rate, hot spot activity must have been much more abundant in the Archaean. At present, 10% of all sea floor volcanism is estimated to result from hot spot activity (16). In the Archaean, it is likely that an even greater percentage of sea floor magmatism would have been hot spot generated.

Greater hot spot magmatism in the Archaean would have increased the incidence of bouyant subduction. Bouyant subduction can be a result of subduction of young oceanic crust or of older oceanic crust with a thickened crustal section (7). Much of the oceanic crust which subducts bouyantly has no volcanism or reduced volcanism. This reduction in volcanic activity as a result of bouyant subduction is most common if the overlying plate has a thickened crustal section. Consequently, an increase in hot spot activity in the Archaean could have decreased the percentage of subducting plates causing magmatic activity in the overriding plate, particularly when the overriding plate was relatively cold, thick continental lithosphere.

Areas of hot spot magmatism generally have a thickened pillow basalt section and a greater abundance of highly permeable rocks. These thickened pillowed sections can support more intense hydrothermal activity. Increased hydrothermal alteration at hot spots, particularly ridge-centered hot spots, could also have contributed to the relative abundance of Archaean massive sulfide deposits.

In conclusion, it is probable that many of the differences in preserved Archaean and Phanerozoic greenstone belt/ophiolite terranes can be explained as a result of a difference in the relative importance of different plate tectonic processes. This difference is a direct result of the increased internal heat production of the earth in the Archaean.

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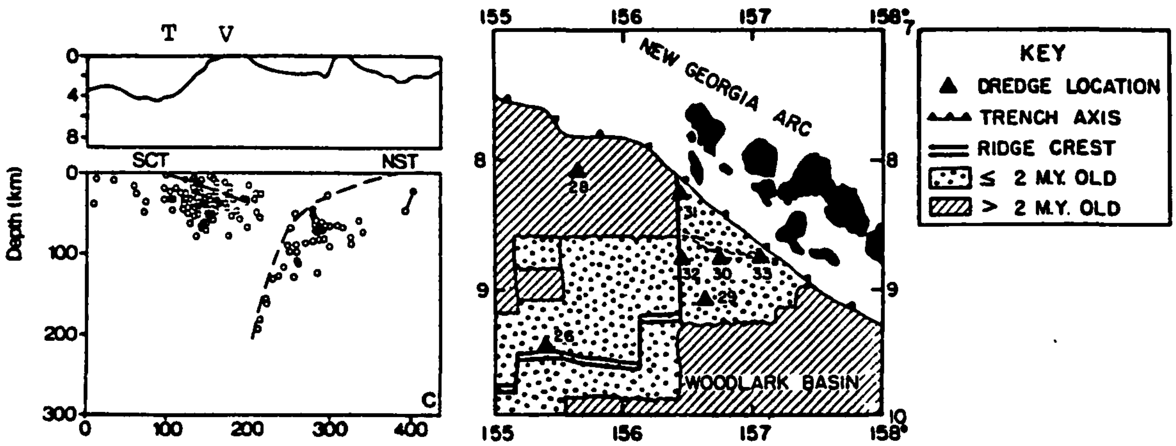

Figure 1. (left) Benioff zone of the New Georgia arc (SCT), after (12); T = Trench, V = Volcanic Line. (right) Volcanoes of the New Georgia arc, after (10).

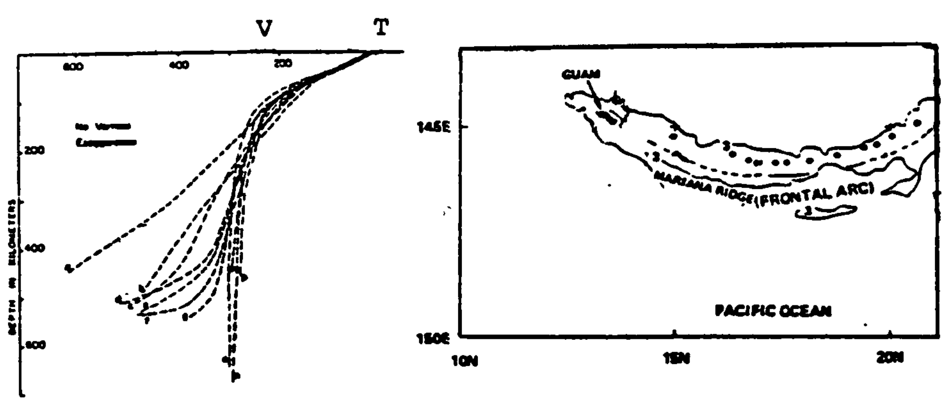

Figure 2. (left) Benioff zone of the Marianas arc, after (13); T and V as in Figure 1. (right) Volcanoes of the Marianas arc are designated by dots, after (14).