(Fig. 1). Subsequent melting of hydrous peridotitic mantle yields basaltic magmas of the "island-arc tholeiitic" suite, as developed for example in the Tonga-Kermadec section of the S.W. Pacific arcs.

At greater depths (100 - 250 km) the former oceanic crust, now transformed to eclogite, undergoes partial melting, producing hydrous rhyodacite-rhyolite liquids rich in K and related trace elements (Fig. 2). The peridotitic mantle overlying the Benioff Zone is modified toward pyroxenitic compositions by reaction with these liquids. Subsequent partial melting of this modified mantle produces magmas of basaltic to basaltic andesite compositions, richer in K than those associated with the island-arc tholeiitic series. Intermediate pressure fractionation of these magmas, involving mainly olivine, calcic clinopyroxene and amphibole, allows evolution toward andesitic magmas. Superimposed lower pressure fractionation processes yield a wide range of "calc-alkaline", "high-K calc-alkaline" and "shoshonitic" lavas, such as those developed in several of the S.W. Pacific arcs.

Rocks of a "high-K alkaline" suite, dominated by strongly silica-undersaturated leucite basanites, tephrites and phonolites, are relatively rare in island arcs, where they are usually associated with Benioff Zone depths of 250-400 km. Good examples occur in the Sunda arc of Indonesia, particularly in the island of Java. The origin of magmas of this suite, and associated sodic alkaline suites, may not be related primarily to the dehydration or melting of subducted oceanic crust, but may reflect the tapping of the mantle low velocity zone behind the main volcanic arc during tensional faulting associated with the formation of interarc basins on sialic crust.

References

GREEN, D.H., 1973: Experimental melting studies on a model upper mantle composition at high pressure under water-saturated and water-undersaturated conditions. *Earth Planet. Sci. Letters,* 19: 37-53.

GREEN, T.H., 1972: Crystallization of calc-alkaline andesite under controlled high-pressure hydrous conditions. *Contr. Mineral and Petrol.,* 34: 150-166.

MYSEN, B.O., and BOETTCHER, A.L., 1975: Melting of a hydrous mantle: II. Geochemistry of crystals and liquids formed by anatexis of mantle peridotite at high pressures and high temperatures, as a function of controlled activities of water, hydrogen and carbon dioxide. *Jnl. Petrology* (in press).

NICHOLLS, I.A., 1974: Liquids in equilibrium with peridotitic and mineral assemblages at high water pressures. *Contr. Mineral and Petrol.,* 45: 289-316.

NICHOLLS, I.A., and RINGWOOD, A.E., 1973: Effect of water on olivine stability in tholeiites and the production of silica- saturated magmas in the island arc environment. *Jnl. Geol.,* 81: 285-300.

RINGWOOD, A.E., 1974: The petrological evolution of island arc systems. *Jnl. Geol. Soc. Lond.,* 130: 183-204.

STERN, C.R., 1974: Melting products of olivine tholeiite basalt in subduction zones, *Geology,* 2(5): 227-230.

GEOCHEMISTRY OF THE VOLCANIC ROCKS OF THE SUNDA ISLAND ARC OF INDONESIA

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The Sunda arc represents the collision zone between the India and Asia (or China) plates. The Sunda volcanic arc extends from north of Sumatra, along the southwestern coast of Sumatra, through Java, Bali, Lombok, Sumbawa, Flores and the Lesser Sunda Islands, after which it becomes known as the Banda arc. There are a variety of tectonic environments represented along the arc. In Sumatra the crust is $\sim$40 km thick and Palaeozoic granites show it to be relatively old. The Benioff zone as defined by the location of earthquake foci extends only to relatively shallow depths of $\sim$200 km. Beneath Java the crust is somewhat thinner, younger; the oldest exposed rocks being ? Mesozoic, and the Benioff zone extends to $\sim$600km beneath the Java Sea to the north. Further east, the crust is thinner ($\sim$15 km), oceanic in velocity structure and again the Benioff zone extends to great depths.

There are three major volcanic associations represented along the arc.

(1) **The normal island arc association** is the most abundant and widespread, being found along the entire length of the arc. Rocks of this association range in composition from those showing affinities with the island arc tholeiitic suite closest to the trench, over Benioff zone depths of 100-150 km, through a spectrum of calc-alkaline to high-K calc-alkaline varieties more distant from the trench, over Benioff zone depths of 200-250 km. This latter group are sometimes referred to as "shoshonites". Chemically, rocks of this suite have low concentrations of TiO_2, high Al_2O_3, low MgO and a variable, but generally low alkali content. The predominantly basaltic rocks of the island arc tholeiitic suite are geochemically primitive whereas the calc-alkaline rocks are more evolved. The rocks of this association exhibit consistent spatial, geochemical variations normal to the arc; the best defined being that of K which shows an increasing abundance relative to SiO_2 with increasing depth to the Benioff zone. The "incompatible" trace elements such as Rb, Sr, Ba, U, Th, Zr and Hb all behave sympathetically with K and there is a suggestion that $^{87}Sr/^{86}Sr$ ratios increase regularly in the series from the tholeiitic rocks ($\sim$0.7043) to the high-K calc-alkaline rocks ($\sim$0.7050). Elements such as Ni, Co and Cr are characteristically depleted in all the rocks of this association, although they are somewhat more abundant in the tholeiitic rocks.

(2) Rocks of the **high-K alkaline association** are much less common and are predominantly leucite basanites and their derivatives. Volcanoes erupting these lavas are generally found over Benioff zone depths $>$300 km and at present there are only two or three active volcanoes of this type, although there are several more extinct. Chemically, these rocks again have low TiO_2, a characteristic feature of island arc rocks, MgO is much higher than in the normal island arc association and total alkalis are much more abundant, largely reflecting the high K_2O contents. Rocks of this association are highly enriched in the "incompatible" trace elements and are also moderately enriched in the siderophile trace elements. $^{87}Sr/^{86}Sr$ ratios are relatively low ($\sim$0.7043). Thus, despite being geochemically primitive in terms of Mg/Fe ratios and $^{87}Sr/^{86}Sr$ ratios, rocks of this association are also enriched in K and related trace elements.

(3) The third major association is represented by the **rhyolitic tuffs and ignimbrites** which are widespread in

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northern and southern Sumatra. These rocks appear to be related to the peculiar tectonic setting of Sumatra where subduction is oblique, and plate movement appears to be taken up in part at least by movement along the Semangko Fault — a major strike-slip fault which extends along the length of Sumatra. Chemical evidence strongly suggests a crustal origin and it seems that these rocks may represent the last stages of island arc evolution, whereby an island arc is converted into a chemically zoned stratified crust.

MAGNETICS OF THE RABAUL CALDERA

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The Rabaul caldera in East New Britain is a collapse caldera of about 10 km. diameter within which some active volcanism remains. Total magnetic field measurements show large anomalies associated with volcanic centres on the East side of the caldera, but only a small one on Vulcan which is on the West side. This correlates with the contrast between the basalts and andesites erupted on the East side, and the dacite pumice and ash of Vulcan. The absence of a large anomaly field on Vulcan may also be due to its structure, being an ash cone lacking in solid lave flows. A programme of repeat measurements on two potentially active craters on the East side has been mounted in order to detect possible anomaly field changes due to thermal changes.

TIME VARIATIONS IN RECENT VOLCANISM AND SEISMICITY ALONG CONVERGENT PLATE BOUNDARIES OF THE SOUTH BISMARCK SEA, PAPUA NEW GUINEA.

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A striking spatial and temporal clustering of volcanic eruptions has occurred in the Bismarck Volcanic Arc, Papua New Guinea, since late 1972. In the complete arc, six volcanoes have been active during this period, Long Island, Langila, Ulawan, Karkar, Manam, and Ritter Island. Ulawan is located in the eastern (New Britain) half of the arc. The other five are located consecutively in the western half of the arc; no definite historical eruptions are known from any other volcano in the sector containing them. This western half is distinguishable from the eastern half on petrological and geophysical grounds by Johnson (this Symposium). The only western volcanoes with historical eruptions but not active in this present phase, are in the Schouten Islands at the far western end of the arc; this sector is also petrologically distinguishable.

Of the western group of five, two volcanoes have erupted after long periods of apparent repose, 84½ years (Ritter Island) and 78½ years (Karkar), while the other three have erupted fairly frequently during the last 20 years. The character of the eruptions is notable in that four of the five volcanoes produced lava flows, while the fifth (Ritter Island) had submarine eruptions of ambiguous nature. Lava flows in this sector had historically been rare occurrences, except at Manam.

An earlier clustering of volcanic eruptions, fewer in number and more loosely associated in time, occurred in this sector during the 1950s, when four volcanoes, Long Island, Bam, Langila, and Manam erupted between 1953-60. A possible fifth centre, submarine and a little to the northnortheast of Markar, may have erupted during 1951. This clustering occurred during a decade which also contained the notable eruptions at Tuluman in the north Bismarck Sea, and Lamington in eastern Papua, both outside the Bismarck Volcanic Arc. Another Papua New Guinea volcano, Bangana in the north Solomon Islands arc, was active during both the 1950s and 1970s clusters.

Such clusterings suggest an underlying common cause, which is best sought in the processes occurring at the plate boundaries comprising the Bismarck Arc. Volcanism and seismic activity are the two obvious dynamic features of a plate boundary, and it is natural to seek correlations between the two. A list was prepared of all earthquakes of magnitude M 6¼ or greater, from 1947 to the present, which were apparently associated with the plate boundaries at the southern edge of the Bismarck Sea between longitudes 143¼° and 149¾°E covering the western active sector. Maximum earthquake focal depths in this region are about 230 km; occasional very deep earthquakes at the extreme eastern margin of the region were deliberately excluded. The list of M6 events for the earlier part of the period appeared to be incomplete, and consequently all M6 events were excluded.

A strain-release diagram for all these events shows a marked increase in activity in 1951-53, immediately preceding the clustered eruptions of the 1950s, and a less notable increase from 1970-72, prior to the 1970s cluster. The late G.A. Taylor had recognized a "regional stress pulse", determined by earthquake activity, as an important factor in predicting volcanic activity during the 1950s. However, the strain-release diagram also shows peaks of seismic activity in 1947-48, 1959, and 1963, none of which seems to be associated with a **general** increase in volcanic activity; the latter two peaks are caused only by single large earthquakes. A check was also made for association between volcanic activity and more specific strain-release plots for restricted depth ranges, and different parts of the complex plate boundaries in the region. There might be correlations between local seismic activity and particular eruptions, but the evidence for a general increase in seismic activity associated with regional upsurge in volcanic activity is not very convincing.

The nature of the seismic activity, and the occurrence of any other eruptive activity which might constitute a cluster, at the time of the previous eruptions of the long dormant volcanoes, Karkar and Ritter Island, is now known reliably. Certainly these two eruptions, seven years apart, were not as closely grouped in time as at present. Of the other three currently active volcanoes, Manam has an eruptive history demonstrating a rough cyclicity, and from limited information available only from the 1950s onwards, Long Island and Langila might also show cyclic behaviour.

The correlation in time of eruptions at three cyclic volcanoes might occasionally be expected without the need for assuming a common cause, but the correlation with them of eruptions at two long-dormant volcanoes seems too great a coincidence. On the present occasion, the absence of a marked