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Rare-Earth Elements and High Pressures

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to the region sensitive to titanium. Although a minor misbehavior appeared in some of the data, it seems incapable of explaining the values obtained; data in periods not displaying this anomaly gave the same analytical results. Limits are given in Table 1 for groups of elements with masses greater than 61. In addition to the spectra of elements listed in Table 1, those of B, N, P, and Cl have been included in the libraries for the analyses, but have been found to make no contribution to the lunar-sample spectra.

The results presented in Table 1 for the composition of lunar surface material are within the ranges given in the preliminary report for Surveyor V (*1*). The errors assigned now, however, are considerably smaller.

In general, the data for the two lunar samples examined on the mission agree. A major disagreement is in the values for carbon. In view of the uncertainties uncovered in the analysis for this element in terrestrial rocks by this technique, it cannot be concluded that carbon has been detected in lunar surface material. Its abundance is almost certainly less than 2 atom percent.

The amount of sodium, reported earlier only as an upper limit of 2 percent, has now been set at a value of 0.4 percent. In addition, the presence of titanium in significant amounts has been established. The data on the other minor elements speak primarily to their absence in appreciable amounts.

The values for oxygen in Table 1 are slightly greater than required to oxidize the iron to FeO and all of the other metals to oxides. This slight excess of oxygen, if real, may be in the form of water, carbonates, or higher oxides of iron. If the mean values of the lunar surface analyses of Table 1 are converted to an oxide weight composition, the results in Table 2 are obtained.

The more precise results in Table 1 make even more certain most of the conclusions drawn in the preliminary reports: the chemical composition does not correspond to that of the nonvolatile components of the sun's atmosphere, to that of terrestrial ultrabasic rocks, or to that of the most common chondritic meteorites. The low silicon and high iron and calcium values rule out a granitic composition. The preliminary results indicated a similarity in chemical composition with that of terrestrial basalts and basaltic achondrites. The comparison of the present, more precise and comprehensive, data with these two classes of rocks is shown in Fig. 1. The three most abundant elements (oxygen, silicon, and aluminum) still agree within our estimated errors. On the other hand, the low value for sodium and high value for titanium appear incompatible with the composition of most terrestrial basalts; the high value for titanium and the relatively low value for iron are at variance with the content of these elements in eucrites and other calcium-rich achondrites. Thus, there appears to be no common material on earth that matches, in all respects, the chemical composition of lunar surface material at Mare Tranquillitatis. This uniqueness suggests detailed geochemical processes somewhat special to the history of this material. Moreover, the present, more complete, analysis of the Surveyor V data gives evidence that mare materials in different parts of the moon differ in at least one minor constituent. The alpha spectrum at the Surveyor VI mare site (Sinus Medii) differed slightly but significantly from Surveyor V spectra in the energy region sensitive to the presence of titanium (*2*). There is a clear indication that the titanium content at Sinus Medii is less than at the Surveyor V site.

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Rare-Earth Elements and High Pressures

Abstract. *Praseodymium, under very high pressures, shows a magnetic behavior similar to that of cerium at normal pressure.*

One can observe the magnetic behavior of solid solutions of the rare earths in ZrB_{12} under the high pressures exerted by the extreme rigidity of the boron lattice. Of all known dodecaborides, ZrB_{12} has the smallest lattice constant, $a_0 = 7.408$ Å (*1*). We have been able to substitute several atom percent of most rare-earth elements for Zr in ZrB_{12}. The atomic radius of Zr (1.60 Å) is much smaller than the atomic radii of the rare earths, which range from 1.86 Å for La to 1.72 Å for Lu. Since ZrB_{12} is superconducting at 6°K (*2*), an indication of the effect of this pressure on the magnetic configuration of the dissolved

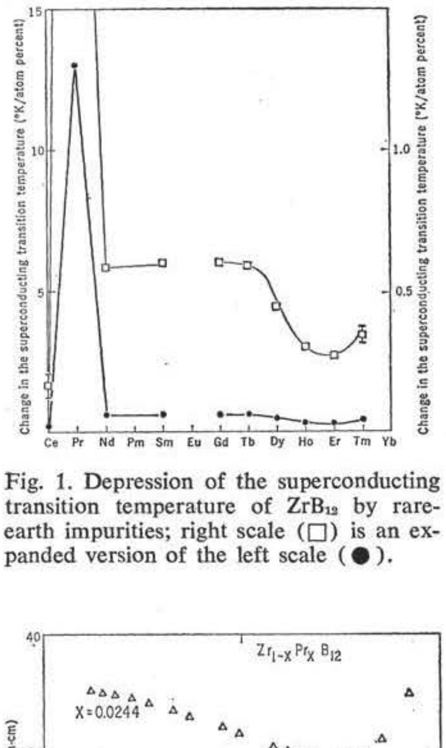

Fig. 1. Depression of the superconducting transition temperature of ZrB_{12} by rare-earth impurities; right scale (□) is an expanded version of the left scale (●).

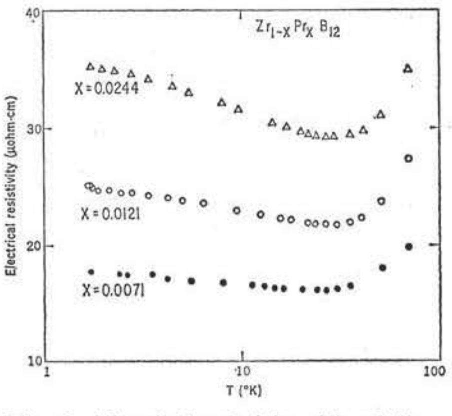

Fig. 2. Electrical resistivity (ρ) of $Zr_{1-x}Pr_xB_{12}$ alloys plotted against the logarithm of the temperature.

rare-earth atom can be seen in the depression of the superconducting transition temperatures. The results are given in Fig. 1.

For rare earths dissolved in pure La the maximum depressions occurred for Ce and Gd, reaching 6°K/atom percent at Gd. For rare earths dissolved in ZrB$_{12}$, on the other hand, there is only one very pronounced maximum which occurs for Pr, reaching close to 13°K/atom percent. The magnitude of this maximum points to a virtual bound *f*-level in Pr, very near to the Fermi surface. This leads us to expect that Pr in ZrB$_{12}$ will also exhibit a resistance minimum, and this is verified in Fig. 2.

Based on an extrapolated lattice constant for hypothetical PrB$_{12}$ of 7.53 Å, the pressure at the Pr site in ZrB$_{12}$ is roughly 200 kb, if we assume that the compressibility of ZrB$_{12}$ is the same as that of pure crystalline boron. At this pressure, Ce is tetravalent and no longer magnetic; this is evidenced by the small depression of the superconducting transition temperature and the lack of any resistance minimum. However, Pr could be either tetravalent with a virtual bound f^1 configuration or trivalent with a virtual bound f^2 configuration. We expect an f^1 configuration to have an effective magnetic moment of $\sim$2.5 Bohr magnetons, whereas an f^2 configuration should have an effective magnetic moment of $\sim$3.6 Bohr magnetons. Inverse magnetic susceptibility versus temperature follows a clean Curie law and gives a value of close to 3.6 Bohr magnetons, thus favoring the f^2 configuration.

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Destruction of Pacific Corals by the Sea Star Acanthaster planci

Abstract. Acanthaster planci, *a coral predator, is undergoing a population explosion in many areas of the Pacific Ocean. Data on feeding rates, population movements, and stages of infestation were collected along coral reefs of Guam and Palau. Direct observations on destruction of Guam's coral reefs indicate that narrow, fringing reefs may be killed as rapidly as 1 kilometer per month. In a 2½-year period, 90 percent of the coral was killed along 38 kilometers of Guam's shoreline.*

Goreau (*1*), in seeking causes for impoverished coral growth in areas of the Red Sea, suggested that predation by a large, sixteen-armed, spiny sea star, *Acanthaster planci* (Linnaeus), the "crown-of-thorns starfish," might be sufficient explanation. Barnes and others (*2*) reported that the same species was destroying large tracts of living coral along the Great Barrier Reef in Australia. Recently *A. planci* was reported from several Pacific islands (*3*). A severe infestation on the reefs of the U.S. Territory of Guam has led to the establishment of a control program under the direction of the University of Guam. Available information indicates that recent population explosions of *A. planci* are occurring almost simultaneously in widely separated areas of the Indo-Pacific Ocean and that these are not short-term population fluctuations of the type reported for numerous other marine invertebrates (*4*).

Although *Acanthaster planci* is a Linnaean species and has been known for a long time, it has been regarded as a great rarity until about 1963, when large swarms were reported by local residents from the Great Barrier Reef near Cairns.

Since 1967 this starfish has killed well over 90 percent of the living coral along 38 km of the coastline of Guam from just below low spring tide level to the depth limit of reef coral growth (about 65 meters). After the death of the coral polyps, the coralla are rapidly overgrown with algae. Most fish leave the dead reefs, with the exception of small, drab-colored, herbivorous scarids and acanthurids.

Other animals feed on coral (*1*), but none so efficiently as *A. planci*. Caged, starved specimens ate mollusks and other echinoderms, but observations showed scleractinian corals of any configuration as the primary diet of undisturbed specimens. Hydrocorals and octocorals were eaten only after the madreporarian corals were gone. *Acanthaster planci* feeds by everting the gastric sac through its mouth, spreading the membranes over the coral, and digesting the soft tissues in place (*1–3*). The skeleton left behind stands out sharply as a patch of pure white until overgrown with algae. On reefs with low *A. planci* densities, feeding was nocturnal and specimens were cryptic during daylight. On reefs with high densities, many animals were found feeding during the day (Fig. 1).

Although *A. planci*, 60 cm in total diameter, were collected, those in the infested areas of Guam averaged 24.2 cm across the arms and 13.8 cm across the disk. The daily feeding rate was observed to be twice the area of the disk. Coral is therefore killed in areas of infestation at a mean rate of 378 cm^2 per animal per day or about 1 m^2 per month. In some localities, with population densities as high as one animal per square meter of reef, all living coral would be eaten in 1 month.

Before 1967, *A. planci* was not common on Guam (*5*). In early 1967, the starfish became abundant on reefs off Tumon and Piti bays (Fig. 2). They were observed feeding actively at depths of 3 to 10 m. The numbers of sea stars increased rapidly, and they were observed in deeper water. Large parts of the reef were completely stripped of living coral before the sea stars moved to adjacent areas. By spring, 1968, almost all of the coral off Tumon Bay was dead. In September of 1968, *A. planci* had spread to Double Reef, and in November divers removed 886 animals from 90,000 m^2 of reef at that locality. At that time, half of the coral of this reef was dead. Coral to the north of Double Reef was alive, although *A. planci* was present in limited numbers. Hazardous weather prevented surveillance of this area from December until late March. By then, the reef was dead for another 4 km, and the main concentration of animals had moved to an area extending 3 km southeastward from Ritidian Point.

Strong wave surge along this northern shoreline prevented the sea stars from entering shallow water until late