seem strange that I here propose that a great fracture crosses one of these chains (the Austral Islands) at a small angle and that islands along the fracture are uplifted, whereas the other Austral Islands are not. I discuss this problem elsewhere (*13*), as well as the evidence for horizontal motion of ocean islands (*14*).

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References

1. C. Darwin, *Coral Reefs* (London, ed. 1, 1842; ed. 3, 1889).
2. W. M. Davis, *Am. Geog. Soc. Spec. Publ.* **9**, (1928).
3. T. W. E. David and G. Sweet, *Roy. Soc. London, Rept. Coral Reef Comm.* **61**, (1904); T. F. Grinsdale, *Challenger Soc. Occ. Papers* **2** (1952); L. V. Pirsson, *Am. J. Sci.*, ser. 4, **38**, 189, 331 (1914); N. D. Newell, *Geol. Soc. Am. Spec. Papers* **62**, 303 (1955); S. Toshio, *Tohuku. Imp. Univ. Fac. Sci., Inst. Geol. Palaeontol., Contrib. in Japanese Lang.* **11**, 22 (1934) and **25**, 1 (1936) (quoted in ref. 4).
4. R. Revelle, K. O. Emery, J. L. Tracey, H. S. Ladd *et al.*, *U.S. Geol. Surv. Profess. Papers* **260** (1954–1957).
5. H. S. Ladd, J. I. Tracey, G. G. Lill, *Science* **107**, 51 (1948).
6. A. J. Carsola and R. S. Dietz, *Am. J. Sci.* **250**, 481 (1952); R. L. Fisher, *IGY World Data Center A, General Rept.* **2** (1958); E. L. Hamilton, *Geol. Soc. Am. Mem.* **64** (1956); H. W. Menard and R. S. Dietz, *Geol. Soc. Am. Bull.* **62**, 1963 (1951); E. L. Hamilton and R. W. Rex, *U.S. Geol. Survey Profess. Paper* **260W** (1957); H. Kuno, R. L. Fisher, N. Nasu, *Deep-Sea Res.* **3**, 126 (1956); J. D. H. Wiseman, *Trans. Linnean Soc. London*, ser. 2, **19**, 437 (1926–36); W. S. Cole, *Cushman Found. Foram. Res. Contrib.* **10**, 10 (1959).
7. P. H. Kuenen, *Deep-Sea Res.* **1**, 187 (1954).
8. J. C. Scholfield, *Nature* **195**, 1191 (1962).
9. H. W. Menard, *Science* **132**, 1737 (1960).
10. R. S. Dietz, *Pacific Sci. Cong. Proc. 7th Meeting, New Zealand* **3**, 338 (1952).
11. R. L. Fisher, *IGY World Data Center A, General Rept.* **2** (1958).
12. F. R. C. Reed, *The Geology of the British Empire* (London, ed. 2, 1949); J. M. Nickles *et al.*, *Bibliog. and Index Geol. excl. North America, Geol. Soc. Amer.* **1–24** (1933–1959).
13. J. Tuzo Wilson, *Can. J. Phys.*, in press.
14. ———, *Nature*, in press.
15. K. Krejci-Graf, *Frankfurt Geol.* **30**, 1 (1956).
16. H. J. Snell and W. H. T. Tams, *Proc. Cambridge Phil. Soc.* **19**, 283 (1920).
17. C. A. Fleming, *Geol. Soc. Australia* **4**, 13 (1957).
18. E. Aubert de la Rue, *Chronique Mines Rech. Miniere* **24**, 162 (1956).
19. O. Ribeiro, *Soc. Geol. Portugal Bull.* **7**, 113 (1948).
20. H. Hausen, *Acta Geog. (Soc. Geol. Fennia)* **15**, No. 2 (1956).
21. J. M. Pires Soares, *Conf. Intern. Africanistas Ocident.*, Sess. 6, Sao Tomé, **2**, 306 (1956).
22. W. L. F. Nuttall, *Quart. J. Geol. Soc. London* **82**, 22 (1926).
23. W. A. Bryan, *B. P. Bishop Mus. Occas. Papers* **2**, 77 (1903).
24. L. E. Nugent, Jr., *Geol. Soc. Am. Bull.* **57**, 135 (1941).
25. L. Owen, *Quart. J. Geol. Soc. London* **79**, 1 (1923).
26. F. D. Power, *Econ. Geol.* **20**, 266 (1925).
27. J. C. Scholfield, *New Zealand Geol. Surv. Bull.* **62** (1959).
28. P. Marshall, *B. P. Bishop Mus. Bull.* **36** (1927).
29. L. J. Chubb, *Geol. Mag.* **64**, 518 (1927).
30. P. Marshall, *B. P. Bishop Mus. Bull.* **72** (1930).
31. ———, *New Zealand Inst. Trans.* **41**, 98 (1908).
32. L. J. Chubb, *Quart. J. Geol. Soc. London* **83**, 291 (1927).
33. E. Jérémine, *Bull. Volcanol.* ser. 2, **21**, 117 (1959).
34. J. Repelin, *Compt. Rend.* **168**, 237 (1919).

24 December 1962

Zirconium and Hafnium in Stone Meteorites

Abstract. *The abundances of zirconium and hafnium in stone meteorites, were determined by neutron activation analysis. Specific radiochemical separations were used to obtain individual zirconium and hafnium samples of high radiochemical purity. The average abundance of zirconium in chondrites for six analyses was 35 parts per million; of hafnium, 0.19 ppm. The hafnium abundances are in good general agreement with the predictions of current theories of nucleosynthesis.*

The abundances of zirconium and hafnium have been determined for five stone meteorites by neutron activation analysis. Radiochemical separation procedures have been developed which separate zirconium and hafnium simultaneously from a 1-g sample (*1*). The abundance of hafnium in our samples is significantly lower than the abundances reported by others.

After irradiation with thermal neutrons, the meteorite samples were dissolved in mixtures of concentrated acids, and aliquots of standard zirconium and hafnium carriers were added to permit determination of the individual chemical yields. The fluoride complexes of zirconium and hafnium were then adsorbed from 10*M* HF on a Dowex 1, X–8, anion-exchange column. The bulk of the major contaminating radionuclides are not adsorbed (*2*). Zirconium and hafnium were simultaneously eluted from the column with 4*M* HCl. Zirconium was separated from hafnium by means of solvent extraction (*3*) from a 2*M* $HClO_4$ solution into 0.025*M* thenoyltrifluoroacetone in benzene. Hafnium remains in the aqueous phase. After back-extraction of zirconium into 10*M* HF, zirconium and hafnium were each precipitated by use of an aqueous solution of mandelic acid (*4*). The zirconium and hafnium tetramandelates were ignited to oxides at 800°C. The chemical yields, calculated on the basis of the carrier added for each element, were variable and ranged from 5 to 50 percent for each element.

The zirconium activity was determined by measuring the area under the 0.76-Mev gamma-ray photopeak of Zr^{95}. The hafnium activity was determined by measuring the area under the 0.48-Mev gamma-ray photopeak of Hf^{181}. No evidence of the Zr^{95} photopeak was observed in the Hf^{181} sample spectra, and no evidence of the Hf^{181} photopeak was observed in the Zr^{95} sample spectra. Tracer experiments demonstrated that the radiochemical purities of the zirconium and hafnium samples with respect to each other were greater than 96 percent. A 512-channel pulse-height analyzer coupled to a 3-by-3-inch NaI crystal scintillation detector was used throughout.

The data obtained to date for the abundances of zirconium and hafnium are given in Table 1. The average abundance of zirconium for the four chondrites is 35 ppm by weight; the average abundance of hafnium is 0.19 ppm. Duplicate analyses on the same batch of powdered meteorite, as indi-

Table 1. Abundances of zirconium and hafnium in meteorites.

Meteorite	Abundance (ppm)		Zr/Hf
	Zr	Hf	
Elenovka chondrite	40	0.19	210
Plainview chondrite (*a*)	31	0.23	135
Plainview chondrite (*b*)	32	0.21	150
Forest City chondrite	37	0.21	180
Pultusk chondrite (*a*)	38	0.16	240
Pultusk chondrite (*b*)	35	0.15	230
Av.	35	0.19	190
Johnstown achondrite	26		

Table 2. Comparison of zirconium and hafnium abundance data as determined by different workers in four meteorite samples.

Meteorite	Zr (ppm)			Hf (ppm)		Zr/Hf	
	Ref. (*6*)*	Ref. (*5*)	This work	Ref. (*5*)	This work	Ref. (*5*)	This work
Plainview		33	30	1.7	0.23	19	130
Pultusk	32	30	38	1.2	0.16	25	240
Forest City	39		37		0.21		180
Johnstown	30		26				

* Spectrographic analyses.

cated by the notations (*a*) and (*b*) in Table 1, provide an index of the reproducibility of the method. The data for hafnium are not in agreement with those obtained recently by Merz (*5*), who reported an average hafnium abundance of 1.4 ppm for five chondrites. The chemical procedures used by Merz did not specifically separate zirconium from hafnium. Chemical yields for both elements were calculated only on the basis of the amount of zirconium carrier added. Fractionation of zirconium and hafnium in the procedures used by Merz may account for the differing results.

Pinson, Ahrens, and Franck (*6*) have analyzed 26 chondrites for zirconium by spectrography. The average zirconium abundance for their samples was 33 ppm, a value which is in good agreement with ours. They reported a zirconium abundance of 30 ppm for the Johnstown achondrite, a value close to ours.

Data obtained by Merz (*5*), Pinson, Ahrens, and Franck (*6*), and by us, for four meteorites where direct comparisons are possible, are given in Table 2. Although there is good agreement among the analyses for zirconium, our values for hafnium are nearly an order of magnitude smaller than the corresponding values of Merz (*5*). While it is possible that the average hafnium abundance for a meteorite may change slightly as replicate samples are processed and chemical yields are improved, there appears to be no reason to doubt that the hafnium abundances in our samples are near the 0.2 ppm level.

Our results are consistent with abundances of 0.21 ppm (*7*) and 0.13 ppm (*8*) predicted by current theories of nucleosynthesis. An average Zr/Hf ratio of 190 for stone meteorites is obtained from our data. Suess and Urey (*9*) used a value of 110 in establishing their abundance curves. Ahrens (*10*) has suggested a possible fractionation of zirconium and hafnium between the earth and meteorites on the basis of Merz's data. On the basis of our data, such a fractionation may still be indicated. However, the new data are in the direction of a depletion of zirconium in the crustal rocks of the earth with respect to the stone meteorites. Much additional data will be required to establish firmly the relationship of zirconium and hafnium in meteoritic and terrestrial materials.

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References and Notes

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2. J. P. Faris, *Anal. Chem.* **32**, 520 (1960).
3. E. H. Huffman and L. J. Beaufait, *J. Am. Chem. Soc.* **71**, 3179 (1949).
4. R. E. Oesper and J. J. Klingenberg, *Anal. Chem.* **21**, 1509 (1949).
5. E. Merz, *Geochim. Cosmochim. Acta* **26**, 347 (1962).
6. W. H. Pinson, L. H. Ahrens, M. L. Franck, *ibid.* **4**, 251 (1953).
7. D. D. Clayton and W. A. Fowler, *Ann. Phys. N.Y.* **16**, 51 (1961).
8. A. G. W. Cameron, *Astrophys. J.* **129**, 676 (1959).
9. H. E. Suess and H. C. Urey, *Rev. Mod. Phys.* **28**, 53 (1956).
10. L. H. Ahrens, *Geochim. Cosmochim. Acta* **26**, 1077 (1962).

6 December 1962

Cytochemical Assay of Interferon Produced by Duck Hepatitis Virus

Abstract. *A microscopic, cytochemical technique for assay of interferon is described in which psittacosis virus is the indicator agent. Interferon, produced in tissue culture cells in response to duck hepatitis virus, is used to illustrate the procedure.*

The properties of the challenge virus have influenced the methods chosen for assay of interferon (*1*). A change of hemagglutin production, of cytopathogenic effect, or of plaque formation has been useful for detection and analysis of interferon action. Assay techniques, however, have not been standardized. Since, for example, one plaque may reflect the activity of an aggregate of virus particles, quantitative determinations remain equivocal. Furthermore, the mechanism by which virus replication is altered by interferon has not yet been clearly defined: an assay procedure which may be of value in the analysis of interferon action utilizes the psittacosis virus particle as the indicator of inhibition. This agent replicates as a visible intracellular chemical indicator system. The replication pattern of psittacosis virus in cells is completed within 48 hours (*2*, *3*). When a series of infected cell cultures are stained by acridine orange and examined by fluorescence microscopy (*4*), the initial infective DNA-staining virus particle which enters the cytoplasm becomes coated with RNA-staining material ("red ball") within 20 hours. The resulting inclusion enlarges and undergoes a sequence of fluorescent color changes from red to orange to yellow to green. The virus induces a dynamic sequence of cytochemical changes coincident with maturation, and substances which interfere with this maturation sequence can be readily detected (*5*). As employed in this study, tissue cells were rendered resistant to psittacosis virus by exposure to interferon induced in tissue cultures of homologous cells by duck hepatitis virus (DHV) (*6*). The virus particle entered the cytoplasm, but the maturation sequence was stopped at the noninfective "red ball" stage.

Chick embryos infected with DHV were emulsified in Mixture 199 (10 percent wt./vol.). This was clarified by centrifugation and stored as stock virus at −40°C. Chorioallantoic fluid from chick embryos infected with TT

Table 1. Effect of DHV-interferon on replication of psittacosis virus in chick embryo cells, as determined by virus assay in McCoy cell by infected cell count method (*8*). Values are particles per milliliter.

Interferon preparation	Time interval (hours) between absorption of virus and addition of interferon					
	0	6	12	20	24	28
109-uv*	0	0	0	0	7.5×10^3	7.5×10^3
110-h†	0	0	7×10^2	3×10^3	8.3×10^3	6.8×10^3
Control	2.02×10^5					

* Interferon prepared from ultraviolet-inactivated DHV. † Interferon prepared from heat-inactivated DHV.

Table 2. Effect of delayed challenge of psittacosis virus on chick embryo cells treated with DHV-interferon. Values are the percentages by which the virus was reduced, as compared with controls.

Interferon preparation	No. of hours of absorption of interferon by cells before addition of psittacosis virus			
	0	3	6	21
109-uv*	100	100	85	73
150-DHV TC†	100	100	100	89

*Interferon prepared with ultraviolet-inactivated DHV inoculum. †Interferon harvested from DHV-infected chick embryo tissue cultures.