MASTER

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REPORT ON CONTRACT NO. AT(11-1)-101 WITH THE U.S. ATOMIC ENERGY COMMISSION ENTITLED "RESEARCH ON THE NATURAL ABUNDANCE OF DEUTERIUM AND OTHER ISOTOPES IN NATURE"

by Harold C. Urey.

This contract came to an end on September 30, 1958. The reports that have been submitted from time to time have given a review of the progress from year to year, and, so far as this final report is concerned, nothing new can really be added except to say that a very great deal of publication has resulted from this contract in standard journals and review papers. This involved the work of my younger colleagues and myself, often working fairly independently. It has also resulted in giving training to a very considerable number of young men whose names appear on the publications that have resulted. These men have left the University of Chicago to occupy very satisfactory positions in quite a number of other laboratories of the world, including one in Sweden, several in Switzerland, and quite a number in the United States. In this report the current work of the last year is given in detail, and we append to the report a bibliography of all the work done under this contract.

K^{40} - A^{40} age determinations: (J. Geiss)

This work was done in cooperation with D. C. Hess and F. Begemann. Geiss has recently published an extensive discussion of this work in Chimia, Vol. 11, 349-363 (1957). He summarizes the previous work done in this laboratory as well as his own with Hess. The chondrites give ages ranging from 4.0 to 4.4 ($\pm$ .1) x 10^9 years. The work by Gerling in the U.S.S.R. agrees generally with this except that he finds lower ages for chondrites which he believes to have been reheated. A check on one meteorite, Bjürbole, shows considerable disagreement in results. Geiss found ages for a number of achondrites ranging from 3.2 to 4.4 x 10^9 years and with larger probable errors. Some of these have been reheated, as shown by their mineral content. One achondrite, Shergotty, gave an age of 0.56 $\pm$ ~ 0.1 x 10^9 years and is thus definitely younger than the others. He also determined the amounts of He^3, H^3 in Norton County and the ratios of the argon isotopes in several meteorites. Spallation due to cosmic rays has occurred and he is able to estimate the time during which some meteorites were exposed to cosmic rays. The Norton County meteorite was so exposed since 260 x 10^6 years ago, while its K^{40} - A^{40} age is 4.4 x 0.7 x 10^9 years. The cosmic ray ages of other meteorites appear to be less. This age for some iron meteorites runs to some billions of years. It appears that cosmic ray intensities have been constant for periods of time comparable to the age of the solar system.

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Gases produced by cosmic rays: (P. Eberhardt)

This study has been continued by P. Eberhardt in collaboration with F. Begemann, continuing the work of Dr. Libby and D. C. Hess of the Argonne Laboratory. They have found a H^3 - He^3 age of 40×10^6 years for the Abbé achondrite. The He^4 - U, Th age is about 3.5×10^9 years, and is thus comparable to, and possibly identical with, that of the oldest chondrites since loss of He^4 as well as A^{40} may have occurred.

Other chondrites have been investigated for He^3 and, assuming the same content of H^3 as the Abbé achondrite, ages from 15 - 60 million years are secured. This is the time since collisional breakup occurred that exposed the stone to cosmic radiation. The He^4 - U, Th ages are again from 3.5 to 4.4×10^9 years and are probably identical with the age of the solar system.

The extraction of lead from meteorites: (R. Marshall with D. C. Hess)

Some years ago Dr. C. Patterson extracted lead from both iron and stone meteorites and estimated the age on the basis of the following assumptions: (1) Uranium and thorium were separated from the iron meteorites at a definite time; (2) the lead of the stone meteorites had the composition of the lead of the iron meteorites at that time and lead and uranium remained together in the stone meteorite from then onwards; (3) there is sufficient uranium in the stone meteorite to produce the observed amounts of Pb^{206} and Pb^{207}. The last condition appeared, on the basis of subsequent work by Turkevich, Reed and Hamagushi, not to be true. The most obvious source of error appeared to be in Patterson's determination of the lead in the stone meteorites. I have been interested in this because of the age problem itself and also because of the problem of the amount of heat generation in the moon and planets. The amounts of uranium and thorium required by Patterson's measurements would produce excessive amounts of heat in the earth and other terrestrial planets. For these reasons, I interested Dr. R. Marshall in these problems. He has worked carefully and systematically on this difficult problem. Whereas Patterson found some 0.5 ppm or more of lead in chondritic meteorites, Marshall finds considerably less lead in other chondrites than those studied by Patterson. This lead is of different isotopic composition from common terrestrial lead. Marshall believes that the amount of radiogenic lead observed is still greater than can be accounted for from the amounts of uranium and thorium observed. This conclusion leads to a complete puzzle as to how the chondrites got their lead, uranium and thorium composition. I personally believe that there are still errors in these determinations and that eventually complete agreement will be secured. The present results, if taken as final, would mean that all age determinations by the Pb^{206} - Pb^{207} and the thorium-lead and uranium-lead methods are meaningless; also that the agreement between the K^{40} - A^{40} and Rb^{87} - Sr^{87} and these lead ages is accidental. The problem has not been settled by these results and is still very interesting. Professor Turkevich and his colleagues are working on these problems and a complete solution may be forthcoming before long.

Marshall has also extracted lead from some igneous rocks and determined the isotopic composition, and has related this to the changing thorium-lead ratio in the earth's surface.

Hess, Marshall and Urey investigated the isotopic composition of silver in meteorites. There was some possibility that the isotopic composition would vary. None was found.

Publications: R. R. Marshall
"Isotopic composition of common leads and continuous differentiation of the crust of the earth from the mantle."
Geochim. et Cosmochim. Acta, 12, 225-237 (1957)

D. C. Hess, R. R. Marshall and H. C. Urey,
"Surface Ionization of silver; silver in meteorites." Science, 126, 1291-1293 (1957)

R. R. Marshall and D. C. Hess,
"Lead from stone meteorites." Abstract of talk given at annual meeting of the American Geophysical Union in Washington, May 1958.

R. R. Marshall and D. C. Hess,
"Lead from some stone meteorites."
Journal of Chemical Physics, 28, 6, 1258-1259
June 1958.

Composition of Meteorites: (T. Mayeda)

Last year, Mele, Mayeda and Urey published a paper reporting the presence of diamonds in the Goalpara meteorite. This was the second time that diamonds were reported in a stone meteorite. The previous publication was by two Russian chemists in 1888. This work has been continued. Diamonds were reported in the Carcote meteorite in 1889. We have recently looked for them in this meteorite and found none. Further work will be done on many chondrites. If diamonds could be found in these objects, a very critical point in the discussion of the origin of the solar system ould be determined, for, so far as we know at present, diamonds can be formed only at high pressures such as those obtaining at the center of the moon or of larger objects.

The chondritic meteorites contain metallic iron-nickel of the α and γ phases. In the fall of 1956 I noted that these small pieces of iron-nickel must be the result of fragmentation of a larger mass. Mrs. Mayeda and I have continued these observations this year with the object of recording the types of iron-nickel fragments that are observed in various meteorites.

Mr. Eugene DuFresne is studying the composition of the carbonaceous chondrites, using X-ray diffraction methods, as a doctor's thesis. These objects contain water and carbon compounds and represent a record of early carbon chemistry. Results are beginning to come in and the work should be much advanced during the next year.

Mr. J. Glasel, for his doctor's dissertation, is attempting to condense free radicals of the kind that may be expected in comets. He has his apparatus in working order and is now beginning experiments. This will be continued during the coming year at Chicago under the direction of Professor J. Mayer.

Publications: H. C. Urey,
"Diamonds, Meteorites and the Origin of the Solar System", Astrophys Journ. 124, 3 November 1956

H. C. Urey, A. Mele and T. Mayeda, "Diamonds in Stone Meteorites," Geochim. et Cosmochim. Acta, 13, 1-4, 1957.

H. C. Urey and T. Mayeda, "The Metal Particles of Some Chondrites" submitted to Geochim. et Cosmochim. Acta 1958

Paleotemperatures.

During the last year we have made many analyses for Dr. Cesare Emiliani while he is getting his own mass spectrometer going. He recently published a popular article in the February issue of the Scientific American. This article results from the work done in these laboratories largely through the support of this contract. It is evident that much exact and quantitative data on the temperatures during the ice ages have been secured. This is an old subject which has been discussed in qualitative ways in the past. Only recently has this quantitative method been available.

Analyses on the isotopic ratios in natural sources of hydrogen, oxygen and carbon have been done for Harmon Craig of the University of California at La Jolla, Meyer Rubin of the U. S. Geological Survey, Lloyd Williams of the University of California at Los Alamos, and J. Lyman of the U. S. Navy Hydrographic Office.

Theoretical and Review Papers by H. C. Urey.

A number of papers have been produced by the writer during the last years which required little monetary support from the contract other than payment for secretarial help. H. E. Suess and H. C. Urey are publishing a somewhat abridged form of their paper of 1956 in the Reviews of Modern Physics on the Abundances of Elements in the Handbuch der Physik. Also, a paper of about 125 typewritten pages on the Atmospheres of the Planets by H. C. Urey will appear in the same volume. During the past year the Guthrie Lecture of the Physical Society and the Hugo Müller Lecture of the Chemical Society, both on aspects of the Origin of the Solar System as deduced from the evidence of the Meteorites and from other studies largely financed by this contract, have appeared in print.

These publications owe much to this contract indirectly. It has been wonderful to have interesting young men about me and to be able to discuss various ideas with them and from time to time make suggestions of worth-while things to do. And it may be that my attempts to understand some of these difficulties have benefited them in their research problems. I am much indebted to the A.E.C. research group for their support of these activities.

Publications: H. C. Urey, "The Moon's Surface Features" The Observatory, 76, 895, Dec. 1956.

H. C. Urey, "Origin of Tektites", Nature, 179, March 1957.

H. C. Urey, 41st Guthrie Lecture, "Meteorites and the Origin of the Solar System", Year Book of the Physical Society, London, 1957.

H. C. Urey, Hugh Müller Lecture, "The Early History of the Solar System as indicated by the Meteorites", Chemical Society Proceedings, London, February 1958.

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H. C. Urey, "The Blue Haze of Mars", Astrophysical Journal Nov. 1958

H. C. Urey, "Comments on two papers by John F. Lovering concering a typical parent meteorite body", Geochim. et Cosmochim. Acta, 13, 335-338 (1958).

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