FJ 1094

UNIVERSITY OF PENNSYLVANIA
Philadelphia, Pennsylvania 19104

VISITING SCIENTIST PROPOSAL

Submitted to: U.S.-Japan Cooperative Science Program
National Science Foundation

Title of Proposal: "Age and Magnetism of Very Young Volcanic Rocks in Japan"

Principal Investigator: Henry Faul — Position: Chairman and Professor

Social Security No: 034-18-8540

School: College — Department: Geology

Proposed Starting Date: July 1, 1973 — Duration: 11 months

FUNDS REQUESTED

$20,574.00

Corporate Name of University: The Trustees of the University of Pennsylvania
(a Pennsylvania non-profit corporation)

Contracting Office: Office of Research Administration
3451 Walnut Street
Philadelphia, Pennsylvania 19104

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Attention: Reagan A. Scurlock

H. Faul
Principal Investigator

Approved: _____
Dean of College

Approved: _____
Vice Provost for Research

Date: November 1, 1972

ABSTRACT

Evidence is mounting that the Earth's magnetic field may have reversed itself, perhaps more than once, during the past 50,000 years or so. Such geologically very recent reversals, if they really are world-wide, would be very useful in geologic correlations and particularly in the study of the history of early man. Magnetic marker horizons in the stratigraphic profile of the archeologist would be of inestimable value. It is proposed to search for reversed remanent magnetization in Recent volcanic rocks of Japan. It seems likely that young reversed rocks could be found and that independent methods for dating them could be developed. If the dating cannot be accomplished with carbon-14, we propose to try the fission track technique and other possibilities, including indirect approaches, such as hydration-rim or thermoluminescence dating. The work will be done at the Geophysical Institute of the University of Tokyo, in cooperation with Professor Minoru Ozima. His laboratory has most of the equipment required for this research, as explained in his letter of September 29, 1972, attached.

INTRODUCTION

The discovery of the reversed remanent magnetism in the volcanic rocks of Puy de Laschamp in France (Bonhommet and Babkine, 1967), opened the eyes of geophysicists to the possibility that the Earth's magnetic field may have reversed itself, possibly more than once, in the geologically very recent past. (For a good recent review of the field, see Dalrymple, 1972) The "Laschamp event" is now dated at 11,000 ±2500 years ago. Clark and Kennett (1972) have found a reversal in the period 13,500 to 17,500 years ago in cores from the Gulf of Mexico. Mörner, et al. (1971) report a brief reversal recorded in the relatively well-dated sediments from Göteborg, Sweden, at about 12,500 years ago. Barbetti and McElhinny (1972) give still another report of a geomagnetic reversal from Aboriginal fireplaces in Australia, dated by Carbon 14 at about 30,000 years ago. They estimate that the reversal lasted about 2500 years. Preliminary work by Elizabeth Ralph of the Department of Geology, University of Pennsylvania (unpublished), indicates the possible existence of a Recent reversely magnetized lava flow in New Mexico, but the result remains to be confirmed. The work is in progress. This would be the only indication of reversely magnetic lava found in an extensive survey of recent volcanics in the western United States.

These short reversals are difficult to detect because volcanic events do not necessarily coincide with magnetic reversals.

Measuring their age is even more difficult because (1) the amount of argon accumulated in such a short time usually cannot be measured with sufficient accuracy; (2) because carbon-14 samples are not usually associated with lava flows; and (3) because other dating techniques are relatively inaccurate. Nevertheless, the great importance of accurate definition of these reversals for the study of recent geologic history and especially the history of early man, make it worthwhile to pursue this difficult research.

Recent volcanic rocks are particularly plentiful in Japan where the background of general geology is also excellent and detailed maps are freely available. Japan is thus the prime area for a survey such as we propose here. Professor Minoru Ozima of the Institute of Geophysics of the University of Tokyo is one of the leaders in paleomagnetic and geochronological research. Recently he also has focused his attention on the paleomagnetism of very young volcanic rocks, and upon hearing of my interest in these studies, has invited me to join him as visiting professor at the University of Tokyo for the academic year 1973-74 to jointly explore this interesting problem (see letter attached).

PROPOSAL

Taking advantage of all the information we can obtain from University and Geological Survey geologists in Japan, we propose to make a survey of likely rocks in Japan and neighboring islands with a portable magnetometer. It is hoped that the survey will find some reversely magnetized volcanic rocks less than 50,000 years old. These rocks will then be examined in the field and in the laboratory and all possible efforts will be made to determine their age by independent methods in the best way possible. The research is open-ended; it may produce only negative results. If the problem were easy, it would no longer be a problem.

In the event that the first phase of the survey is successful, detailed efforts will be made to refine the age of any reversely magnetized rocks that are found, and to establish time correlation with other reported reversals. If a series of recent world-wide magnetic reversals could be confirmed and dated, the resulting time scale would be of great value to the geologist and archeologist.

LITERATURE CITED

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Dalrymple, G. Brent,
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Late Weichselian Paleomagnetic Reversal, Nature Physical Science, 234, 173, 1971

DRAFT OF AN APPLICATION TO IBM REQUESTING A GRANT OF $25,000 FOR MASCA

The University Museum of the University of Pennsylvania, through it's Applied Science Center for Archaeology, has been operating the Akhenaten project in Egypt for the past several years. In one very real sense the IBM Co. has made this research project a success.

Pharoah Akhenaten is the ruler who tried to revolutionize the religion of Egypt when he conceived of monotheism and tried to establish Aten, the Sun God, as a paramount god in Egypt. But his successor returned to the old religion and totally destroyed the vast temple dedicated to the God Aten which Akhenaten had built in what is now Luxor. More than 30,000 carved and engraved stones from this Akhenaten Temple were used in the later construction of Egyptian temples at Luxor. During the past century of excavations at Luxor these individual building stones were identified by the particular artistic style of the Akhenaten period. Hence, they were pulled out and set aside in a large storeroom in Luxor. The University Museum conceived an idea of using a computer to sort out and match up these building stones with their distinctive style of carving and Egyptian language texts engraved on those stones. The IBM Co. supplied the computer time (IBM 360) in Cairo and over the years these 30,000 blocks have been sorted out so that the carvings and the inscriptions can be restored in photographs. It should be observed that all 30,000 stones were individually photographed and the photographs matched up with the use of the IBM computer.

IBM 360

Naturally this project has received a great deal of international publicity, particularly through a documentary film made and broadcast by the British Broadcasting Corporation.

The Applied Science Center of the University Museum continues to develop such innovative techniques in archaeology and many of these innovative techniques involve research abroad such as that with the Akhenaten temple stones. We are, for example, experimenting with various electronic techniques for underground exploration at archaeological sites, with the application of satellite remote sensing devices for discovery of ancient settlement patterns and sites, the development of new techniques for dating archaeological material, and with the recently discovered chemical technique for preserving ancient monument s of all kinds.

Most of our research here is financed by the National Science Foundation, but since this is a U.S. government organization, we have difficulty in raising the funds for foreign travel and research necessary to develop an experiment with these techniques in foreign countries. For example, we must demonstrate this new technique for the preservation of ancient monuments in several foreign countries, we must send our people abroad to collect the materials for developing new archaeological dating techniques and we must do ground surveys in connection with our search instruments - both the electronic instruments on the ground and the satellite instruments in the air. Because of this difficulty in utilizing National Science Foundation funds for research abroad we are sending this proposal to the IBM Co. for a grant of $25,000 a year during the next two years in

order to continue the foreign work of our researchers. To give you some idea of the purpose of MASCA and its accomplishments during the last 15 years of research, we are enclosing examples of MASCA Newsletters and some background papers on the work of MASCA. This is the only organization of its kind in the U.S. and I think the very substantial support by the National Science Foundation for the last 15 years will demonstrate the practical achievements of the Center during that period. We hope that the IBM Co. will give this request its most serious consideration and if you have any other questions about this research, please let us know.

P.S. Suggest you enclose one of those news stories on the Akhenaten project and perhaps other news clippings on the Bristle Cone Pine stories, Ban Chiang and so forth.

News Release
TL Grant

Rainey

DRAFT

For information, call:
Don Fey
ext. 8721, News Office

{E K Ralph made a few small corrections on another copy.}

Thousands of years ago, when ancient craftsmen baked their pottery to harden it, they unwittingly rendered a major service to archaeology that has only recently "come to light" with the aid of modern physics.

For about the last decade, research scientists at the University of Pennsylvania Museum's Applied Science Center for Archaeology (MASCA) have been probing the mysteries of thermoluminescence in pottery-- its tendency to glow under special conditions. Now, with the help of a $61,000 grant from the National Science Foundation, they hope to refine existing knowledge into a routine system that will rival, and in some ways surpass, the widely-known carbon-14 method as a precise and useful archaeological dating tool.

One of the more obvious advantages of thermoluminescent dating (TL) is that it allows pottery, the artifact itself, to be dated, rather than merely related to the age of organic material it is associated with when excavated. This, coupled with the universal use of pottery for the last 9,000 years, plus TL-dating's near-infallibilty in detecting forgeries, endow the technique with the most powerful archaeological potential of all existing dating systems.

The goal of the Pennsylvania team, headed by Dr. Froelich Rainey, Museum director, and Elizabeth K. Ralph, associate director of MASCA, is to resolve the

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intrinsic questions and uncertainties that have so far limited this potential and hampered absolute age determinations.

The phenomenon of thermoluminescence was first noted by the English physicist and chemist, Robert Boyle, in 1663. Its basic principle is that energy, absorbed and stored in inorganic material, can be stimulated by thermal agitation and released in the form of light. In the case of pottery, traces of radioactive impurities (uranium, thorium and potassium) within the potter's clay bombard its other constituents with alpha, beta and gamma rays and raise certain electrons to metastable, or slightly unstable, levels. When the clay is heated, these metastable electrons fall back into stable positions--emitting photons of light as they do so--and become trapped in "faults" in the crystal lattice of the clay.

Thus, when the initial firing dissipated the natural thermoluminescence accumulated during geological time, the pottery's "TL clock" was set at zero from an archaeological point of view. As the centuries pass, however, the pottery gradually reacquires its TL sensitivity at the rate of about 100 rads a century. (By way of illustration, the radiation in a dental x-ray equals about 5 to 10 rads.)

Consequently, when the pottery is reheated in the laboratory, the level of TL observed by photomultiplying devices is indicative of the accumulated radiation damage, and therefore, the amount of time that has elapsed since the pot was originally fired. The older the pottery, the greater the glow that can be observed.

During 1968, more than 40 tests of "unknowns" and checks for authentication were made at MASCA that have already proved of value to archaeology. In addition, TL dating methods are now both supplementing and supplanting radiocarbon dates for some objects.

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For example, because of fluctuations in carbon-14 dates for the period between 1500 and 1700 A.D., TL dates have been accepted as the more reliable ones for samples from a shipwreck off the north coast of Jamaica, placing it at an age appropriate for Columbus's flagship, the Santa Maria.

TL dates are also becoming important for early sites in Greece and Turkey where archaeologists previously had to rely entirely on carbon-14 dating which has recently become suspect for certain time periods. A cup purported to have come from Haçilar, Turkey, for instance, was TL-dated to 5100 B.C. which indicates that the cup may well have come from that site. In other cases, especially with Etruscan statues on display in museums for decades, TL-dating was able to determine that the objects were fired only within the last 100 years, and thus exposed them as fakes.

But making the system work is far more complicated than it seems, and perfecting it may prove even more difficult.

For one thing, it is essential that rapid, controlled heating of thin, uniform layers of powdered potsherds take place so that the comparatively weak TL light can be detected and measured before it is burned away by the onset of heat radiation.

In addition, age correspondences for known-aged samples based on natural TL glow curves and alpha particle bombardment rates alone yield extremely poor results. Metastable electron accumulations that cause the glow in ceramics depend upon variations in their susceptibility to radiation damage, so it is necessary to obtain a correction factor by duplicating this original radiation damage in a much shorter time.

This is accomplished by bombarding the depleted natural TL sample with

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artificial radiation, then reheating it after a two-week delay that permits the newly-trapped electrons to stablilize. This artificial glow curve is then used to construct the correction factor for subsequent natural TL measurements of the same family of samples.

In this manner, a "specific glow" level can be established for the age of the pottery through a formula which roughly calls for the natural glow level to be divided by the artificial glow level times the natural dose rate.

If the sample involved happens to be of known-aged pottery, then its specific glow can be used for absolute dating of all its contemporary artifacts regardless of pottery type or site of origin.

Significant changes in MASCA's techniques in recent years, including better sample preparation, and the installation of a linearly-programmed heating control system and a more sensitive thermoluminescence reader, have improved results to the point where the age deviation for fine-grained pottery dating back to 700 B. C. is now on the order of $\pm$ 100 years. A more precise calibration curve for measuring samples of unknown age has also been established.

"We feel that we have now demonstrated that TL will provide a reliable method of dating pottery," says Dr. Rainey, "but as with all techniques, there are still many questions to be answered and experiments to be performed."

One of the major problems to be solved, according to Miss Ralph, is the clarification of the quantitative theory of the fundamental mechanism of thermoluminescence: "Contributions from radioactive elements in the soil, and possibly cosmic rays, are complicating factors," she notes, "Also, since the inherent natural radioactive bombardment consists of a variety of radiation, their effects

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in producing radiation damage may differ."

In clays, she points out, the predominant elements are uranium, thorium and potassium. The first two emit alpha, beta and gamma rays in their decay series, while potassium-40 emits mostly beta, plus a small fraction of gamma rays. Most of the work at MASCA has been confined to studying the effects of alpha, beta and x radiation, the latter being used in connection with artificial dosages.

"One of our more serious intrinsic problems," says Miss Ralph, "involves our efforts to determine why most of the thermoluminescence in pottery is due to the quartz components of the clays, when most of the inherent radiation is contained to a large extent in the other components." Presently, magnetic separations are being made on samples of coarse-grained pottery to see if there is a difference in the behavior of quartz in pottery and quartz alone.

Because it has been well-established that alpha radiation accounts for most of the total dose received by ceramic artifacts, attempts are underway at MASCA to irradiate pottery samples with an alpha source to measure its effects. The short range of the alpha particle makes such experimentation exceedingly difficult in comparison with measuring the effects of other particles.

It is believed, however, that the alpha effect differs both quantitatively and qualitatively from the effects of other radiations, mainly because its short range compared to its energy results in the whole of its energy being converted within a relatively small volume. This could lead to the formation of new defects and trapping centers in the crystal lattices of ceramics at dose levels that would be insignificant for other radiation.

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In addition, says Miss Ralph, although the connection between the inhomogeneity and coarseness of ancient ceramics with the alpha dose rate is believed to be important, it has been little investigated until now.

"It is important to know the range of alpha particles in clay so we can assess the effect of variable grain sizes and inhomogeneity," she says, "~~because~~ AND this has never been determined."

At present, only MASCA and the Research Laboratory for Archaeology and the History of Art at Oxford University under the direction of Dr. M. J. Aitken, have announced successful applications of thermoluminescence for archaeological purposes, and both laboratories are now demonstrating with/the dating of ceramic materials of an unknown age just how significant the technique will eventually be for archaeology in general.

MASCA's analysis of ceramic materials of unknown age is now providing the first dates for prehistoric West African cultures. In Iran, where radiocarbon materials are unavailable for long sequences of Neolithic cultures, thermoluminescence is filling in the gaps. And in the Mediterranean area, TL-dating for cultural sequences from Neolithic and Bronze age epochs is just getting underway.

"This is a stage in which archaeologists are just beginning to learn about the successful applications of thermoluminescence," says Dr. Rainey, "but with only two laboratories available for dating it will be some time before it reaches the general acceptance of carbon-14 techniques. There is little doubt, however, that within the next few years the number of thermoluminescent dating stations installed for archaeology will be comparable to those currently engaged in radiocarbon dating."

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