EXCHANGE OF LYOTROPIC SERIES CATIONS BY MICACEOUS VERMICULITE
AND ITS WEATHERING PRODUCTS DETERMINED BY ELECTRON MICROSCOPY
AND RADIOCHEMICAL ANALYSIS

Progress Report

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TECHNICAL PROGRESS REPORT

Marion L. Jackson -- Principal Investigator*

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Abstract

(200 words or less)

The problem of hydrolysis of UO_2^{2+} during the determination of surface charge of micas was eliminated by the washing with $0.01\text{M } \text{UO}_2(\text{NO}_3)_2$ of pH 2.4 and then blotting off the liquid. The replica method of determining the ^{235}U fission tracks induced by thermal neutrons was developed to give a constant HF etching time to make the tracks visible. The replica method was also applied to the determination of the U concentration in micas and their age-dating.

Diverse divalent cations in trace concentrations were found to adsorb specifically (i.e. in 1M NaNO_3) on hydrous oxides of Fe and Al. The results with $^{90}\text{Sr}^{2+}$ and $^{45}\text{Ca}^{2+}$ were published; those with Cd, Zn, and other transition and heavy metals were submitted for publication. Insight into fixation of cations such as $^{137}\text{Cs}^+$ was provided by determination of the kinetics of the mica-vermiculite reaction in relation to partial pressure of CO_2 , and by high resolution electron microscopy, revealing images of interlayer wedge configurations.

Aerosol size quartz had less variable oxygen isotopic ratios in eolian than fluvial systems; also, its trace element concentrations as well as isotopic ratios were useful in assigning provenance. Quartz of chert origin was revealed electron microscopically as clusters of subhedral crystals.

Documentation and Collaboration

This progress report is submitted pursuant to Article B-XXI of the Contract, No. E(11-1)-1515 which has been in operation since June 1, 1965. Under this contract to April 26, 1976, 39 scientific papers have been published (six reprints are attached) or accepted for publication, six additional papers have been submitted for publication, and eight others are in various stages of development for publication (all listed near the end of this report). During the time the contract has been in force nine Ph.D. students have worked on the project (8 now placed in jobs) and 11 Post-doctoral Project Associates have participated in the work at Madison. Numerous other scientists, on campus and off-campus throughout the world have actively participated in the research, through an International Consortium for Interinstitutional Cooperation in the Advancement of Learning (ICICAL) organized by the Principal Investigator. Major cost-sharing has been achieved because of the interest in cooperating with this project of people who are otherwise supported. Significant research results have been obtained through this collaboration, including co-publication with the collaborators (resulting publications, with cooperating authors, are listed near the end of this report). The C00-1515 reporting status is summarized in the last two pages of this report.

I. Measurement of cation exchange or surface layer charge, U concentration, and age of micas weathering to vermiculite

a. Surface layer charge measurement by exchange saturation with uranyl cations and thermal neutron activation. Natural ^{238}U fission particle tracks or those of ^{235}U formed by thermal neutrons in a reactor become visible by scanning electron microscopy after HF etching (Lee, Jackson, and Sachs, 1974)*. Therefore, a replica method for determination of surface layer charge density/micas was developed by uranyl saturation, washing with UO_2^{2+} , attachment to a substrate (section b, below), thermal neutron activation, etching, and fission particle track counting. Micaceous mineral flakes were UO_2^{2+} saturated by washing with $0.5\text{M } \text{UO}_2(\text{NO}_3)_2$. To avoid UO_2^{2+} hydrolysis while washing excess salt from the flakes surfaces, three 1-hr washings were given with a $0.01\text{M } \text{UO}_2(\text{NO}_3)_2$ in $0.005\text{M } \text{HNO}_3$ solution (pH 2.4), a composition based on the hydrolysis characteristics of the salt (Lee and Jackson, in preparation). Each saturated and washed flake was pressed between filter papers three times to remove the excess solution. That a negligible amount of excess salt from the dilute washing solution remained was established by coverglass controls. To standardize HF etching time, the replica method (section b, below) was employed. The exchangeable UO_2^{2+} cations retained (mean $3.6 \pm 0.2 \times 10^{-7}$ meq cm^{-2} , Table 1), on the cleavage surfaces of various micas were nearly

* (Authors, date) refers to publications or manuscripts accepted for publication, given in the first list of references appended. (Authors, date, submitted) refers to manuscripts submitted for publication, in the second list of references appended. (Authors, in preparation) refers to manuscripts in the process of being prepared, in the third list of references appended.

Table 1. Uranyl cations retained on the surface of micas and vermiculites after washing with two dilute uranyl solutions

Samples	Source	UO_2^{2+} retained on surface after washing with	
		Solution A* (10^{-7} meq cm^{-2})	Solution B†
<u>Micas:</u>			
Muscovite	Mitchell, NY	5.01	3.66
Muscovite	Unknown	4.70	3.74
Lepidolite	Western Australia	4.87	3.27
Biotite	Bancroft, Ontario	5.34	3.87
Phlogopite	Herimer, NY	5.33	3.61
Lepidomelane	Faraday, Ontario	4.97	<u>3.34</u>
Mean $\pm$ Std. Deviation (1 sigma) 3.58 $\pm$ 0.23			
<u>Vermiculites:</u>			
K-vermiculite	Transvaal, South Africa		12.48
K-vermiculite	Libby, MT		14.59

* Solution A; 0.02 M $\text{UO}_2(\text{NO}_3)_2$ in 0.005 M HNO_3 .

† Solution B; 0.01 M $\text{UO}_2(\text{NO}_3)_2$ in 0.005 M HNO_3 .

equivalent to the theoretical surface charge (cation exchange capacity, 3.5×10^{-7} meq cm^{-2}), showing that the problem of hydrolysis was eliminated. Uranyl cations were found to hydrolyze from the cleavage surface by washing with water, 100% ethanol, or acetone. Uranyl cations in the interlayers near broken edges and crystallographical steps were retained and these areas were avoided in track counting on the planar surface areas.

Uranium on the unblemished mica planar surface increased with increasing uranyl concentration in dilute uranyl washing solutions, because some of the UO_2^{2+} from the dilute salt solution remained. At the same UO_2^{2+} concentration, the uranium on the surface increased with increasing solution pH from 2.5 to 3.5, because polymeric ions such as $\text{U}_2\text{O}_5^{2+}$ and $\text{U}_3\text{O}_8^{2+}$ formed and a higher uranium retention by the negatively charged mineral surface resulted.

Uranyl cations replaced much of the interlayer cations from vermiculites even when K, Rb, and Cs presaturation and drying from 110°C were employed. Strong adsorption of uranyl cations (not replaced by neutral salt solution) occurred in the defects of micaceous minerals, which are extensive in those of soils and sediments.

The mica layer charge may depart from theoretical by several percent because of excess OH^- or O^- content (Eugster and Wones, 1962; Foster, 1964; as reviewed in Veith and Jackson, 1974). This method, as developed, is simple, sensitive, and fast as compared to conventional methods. It is especially valuable because it minimizes error arising from structural defects at broken edges, a problem encountered earlier (Mokma et al., 1970). It is proposed to prepare this series of results on layer charge density for publication.

b. Uranium concentration and age determination by neutron activation of native ^{235}U in micas. An age of 4.1 ± 0.2 million years was obtained on small mica flakes, obtained from horizons of a cold-region soil from Antarctica, by the fission particle track replica method. By this new method, the pedogenic micas of the Antarctic soil were noted to contain 0.5 to 1.6 ppm of U, and to be 20 to 50 times higher in uranium than the biotite mica of the parent igneous rock (0.03 ppm). This concentration of uranium by weathering may be of significance to uranium energy resources. This age is somewhat greater than the minimum time since the Vanda (latest) glaciation in the Wright Valley, based on K-Ar dating. The dioctahedral mica flakes have developed as K mica replacement of plagioclase feldspar grains, increasing from subsoil to surface soil. Studies by the standard fission track method showed that the mica flakes were too fragile to survive the HF etching treatment, and thus fission track counts could not be obtained directly. A fission particle track replica method was then developed (Jackson, Lee, Ugolini, and Helmke, 1976, submitted), whereby the tracks could be counted on a low-U muscovite substrate after thermal neutron activation in a reactor and HF etching. The U content of mica in the fine sand fraction was most easily determined. The spontaneous fission tracks of the clay fraction was determined by ^{235}U activation replica tracks, on the basis that the spontaneous tracks were the same, per unit of U, as the fine sand flakes. The results from all size fractions were then consistent. It is proposed to work out a method of mounting the fine fractions so that their ^{238}U (spontaneous) track counts can be made. The method is expected to be of help in U fuel exploration.

II. Studies of fission product adsorption and fixation processes and structures

a. Specific adsorption of divalent cations of the alkaline earth type and transition and heavy metal types by hydrous iron and aluminum oxides.

The findings that trace amounts (10^{-6} M) of $^{90}\text{Sr}^{2+}$ and $^{45}\text{Ca}^{2+}$ are adsorbed strongly by hydrous oxides of iron and aluminum, even in the presence of 1M NaNO_3 were published (Kinniburgh, Syers, and Jackson, 1975). Specific adsorption of zinc and cadmium studies on hydrous oxides of iron and aluminum, showing similar effects at 10^{-3} to 10^{-7} M in 1M NaNO_3 were found to be comparable (Kinniburgh, Sridhar, and Jackson, 1976, submitted). These results, when presented before the 15th Symposium at Battelle, created considerable interest because many workers were puzzled as to why 1M salts did not replace traces of divalent metals. Evidently, a coordination bonding of $(\text{Fe,Al})-\text{O}-\text{M}^{2+}$ is established at the gel surface, which renders a whole series of the M^{2+} cations irreplaceable by M^+ , although these are replaceable by H^+ below a cation-specific pH (Kinniburgh, Jackson, and Syers, 1976, submitted).

The adsorption of alkaline earth, transition and heavy metal cations occurs even when hydrous oxide gels are positively charged, i.e. the adsorption is "specific" and occurs over varying pH ranges (pH 3 to 9) for different cation types. This specific adsorption occurs well below cation concentration limits set by solubility products of the divalent cation hydroxides, and at low fractions of hydroxide complexing ($\ll 1\% \text{MOH}^+$). Although chloride forms strong complexes with Hg, chloride does not enhance the adsorption of Hg. The presence of acetate enhances ^{65}Zn adsorption but

the presence of chloride does not. Although only one H^+ was released to solution per cation of the ^{90}Sr or ^{45}Ca type adsorbed, 1.7 H^+ were released per ^{65}Zn ion adsorbed (Kinniburgh and Jackson, in preparation). Specific adsorption, by iron and aluminum gels common to soils, of a wide range of cations present in fission products has significance for the movement of these contaminants in ground waters, and completion of this work is proposed.

An isotopic dilution technique with ^{59}Fe , for the determination of aqueous Fe^{3+} concentrations down to 0.1 ppb of Fe ($1 \times 10^{-10} g Fe cm^{-3}$), is under study (May, Helmke, and Jackson, in preparation). The method is expected to be useful for studies of water composition in relation to soil reactions, reactor corrosion, mine spoils drainage, and other areas of concern in energy research and development.

b. Layer sequences by high resolution electron microscopy in relation to cation fixation structures. Residual micaceous high-charge zones in phyllosilicates may be significant in the retention of fixing cations, including the fission product $^{137}Cs^+$. Micaceous occlusions in kaolinites have been observed by ultramicrotomy of epoxy-embedded phyllosilicates and high resolution electron microscopy of the carbon-coated thin specimens (Lee, Jackson, and Brown, 1975a). Electron optical fringes (images) of wedges and frayed-edges were photographed in weathered micaceous vermiculite samples (Lee, Jackson, and Brown, 1975b). A visual model was thus provided of cation fixation structures thought to be specific for Cs^+ sorption and fixation (Mokma, Jackson, Syers, and Stevens, 1973). The above observations also indicated the presence of hydroxy metal interlayers which probably

decrease the Cs^+ fixation capacity by lowering the layer charge (Dolcater et al., 1972) as well as by propping the interlayers open. These hydroxy interlayers may be active in adsorption of divalent cations including those of the $^{90}\text{Sr}^{2+}$ type (Kinniburgh, Syers, and Jackson, 1976, Fig. 1).

The partial pressure of CO_2 in aqueous suspension (simulating seasonal changes in soil atmospheres) affects fixation of K^+ , and by analogy of $^{137}\text{Cs}^+$ and other fixing cations, from rain by soil micaceous vermiculites (Henderson, Doner, Weaver, Syers, and Jackson, 1976). The rates of layer charge change and the fixing reactions are sufficiently fast, that the mica-vermiculite reaction is important to effective retention of fixing cations from nuclear wastes that may enter the ground water. Micaceous argillaceous sediments (such as shales which have been used as Cs^+ waste adsorbants) were found to contain extremely thin crystal packets of mica (a few 10A-layers thick) within the particles when a series of samples was studied by ultramicrotomy-high resolution electron microscopy (Fig. 1, Progress Report C00-1515-56, gives an example). These packets of mica layers have high specific surface which may be responsible for sorption and fixation of cations such as $^{137}\text{Cs}^+$ in the interpacket spaces. Electron micrographs of a series of the argillaceous sediments have been made, and additional selected samples are being examined, as the results are interpreted (Jackson, Lee, Brown, and Veith, in preparation).

Fig. 1 -- Retention against pH curves for eight divalent cations (each present at $0.125 \times 10^{-3} \text{ M}$) from a 1 M NaNO_3 system: (a) fresh Fe gel (0.093 M Fe); (b) fresh Al gel (0.093 M Al).

III. Aerosolic minerals in dusts which fix radioactive nuclear fission products

a. Oxygen isotopic tracing of dust origin. Radiotracer studies have shown that aerosolic dusts (Jackson et al., 1973, 1974) of the atmospheric weather zone (troposphere) are active in sequestering of fission products, particularly $^{137}\text{Cs}^+$ (Syers et al., 1972), as summarized in earlier reports.

That variation in oxygen isotopic composition of fine silt-size quartz (size characteristic of dusts) is mainly a function of diversity of source (igneous-metamorphic quartz mixed with low temperature quartz sources) rather than oxygen isotopic exchange in an outer skin was shown by stripping off of the outer 35 to 45% of the quartz with HF (Sridhar, Jackson, and Clayton, 1975). Quartz oxygen isotopic composition did not change during quartz isolation from soils and sediments by pyrosulfate fusion and hydro-fluorosilicic acid treatment (Jackson, Clayton, and Sayin, 1976, submitted). Euhedral morphology of chert particles and overgrowths on quartz grains (low temperature quartz) were shown by scanning electron microscopy (Sayin and Jackson, 1975) and therefore quartz particle morphology, to a certain extent, may also be used as an indicator of provenance for aerosolic and soil silts. Use of oxygen isotopic composition in fine silt-size quartz as a guide to provenance would be impaired if the isotopic composition changed much under the environmental conditions in the deposit but present studies indicate that this is not a problem (Clayton, Jackson, and Sridhar, 1976, submitted). Quartz oxygen isotopic ratio, therefore, appears to be a reliable indicator of provenance.

Aerosolic dusts containing micaceous vermiculite are deposited in

Hawaii (Jackson et al., 1971) and in Pacific pelagic sediments (Clayton et al., 1972) These dusts contained quartz having oxygen isotopic ratios ($\delta^{18}\text{O} = 17.6 \pm 0.3 \text{ o/oo}$, $\pm 2 \text{ sigma}$) in the North Pacific area. In the South Pacific area, the quartz of both in dusts and pelagic sediments had lower values (12-15 o/oo) (Mokma et al., 1972). A check into the fine silty sediments of South Africa (Le Roux, Clayton, et al., under study) showed the same low range for the Southern Hemisphere continent opposite the South Pacific area, so the trend is apparently global. Both sets of values are intermediate between those of igneous-metamorphic (high temperature) quartz and quartz of chert in sediments (low temperature origin), but in different proportions. A composite mixture of these two sources in dusts, silty sediments, and soils formed thereon was postulated as the source of atmospheric dusts. To test this, the oxygen isotopic ratios ($\delta^{18}\text{O}$) of whole shale quartz, and of the fine silt (1-10 μm) fraction (long range aerosol size) of shale quartz, were determined ($20.7 \pm 1.2 \text{ o/oo}$) for 30 marine shale quartz fine silts representative of soil parent material (via glacial, fluvial, and eolian processes) from the Phanerozoic geologic column in the midcontinental U.S.A. (Churchman, Clayton, Sridhar, and Jackson, 1976). The range and standard deviation is wider than for Pacific area aerosolic quartz, suggestive of more homogenization of the aerosols by wind mixing. As another example, the 1-10 μm quartz fraction of loess in a high-dolomite area of Wisconsin has oxygen isotopic ratios closer to that of chert, $\delta^{18}\text{O} = 22 \pm 2 \text{ o/oo}$, while down river (in Mississippi) an increase in the content of quartz of igneous rock origin lowered the loess quartz numbers to $17.5 \pm 1 \text{ o/oo}$ (Clayton, Jackson, and Sayin, in preparation). The fine silt size quartz of 13 composite samples of wind-eroding soil taxa of

southwestern U.S.A. were then determined to average 19.6 ± 0.2 o/oo (Sridhar, Jackson, et al., in preparation), which suggests further that soil formation and wind erosion are responsible for narrowing the oxygen isotopic ratio range by compositing from diverse sources. The nearly ubiquitous occurrence of $^{137}\text{Cs}^+$ fixing micaceous vermiculite in soils and sediments is likewise accounted for.

An opportunity for gaining a major insight into large scale dust systems was presented through cooperation with a program of the National Center for Atmospheric Research (NCAR) and the Soil Conservation Service (SCS, USDA), with relatively limited commitment from COO-(11-1)AT-1515 resources. Tropospheric aerosols from major dust storms arising in cultivated agricultural areas in western Texas and adjacent areas of New Mexico, Oklahoma and Colorado were collected by NCAR with a ground-based airturbine sampler with stack 3-m high and by airplane-borne dust samplers. The oxygen isotopic ratios ($\delta^{18}\text{O}$) so far determined fall in the interval 19 ± 1 o/oo (Gillette, Clayton, et al., in preparation). The oxygen isotopic ratios of the aerosol-sized quartz from the dusts indicate that they could be entering the storm systems moving northeast through the mid-continent (Jackson et al., 1973), and some meteorologists relate the dusts to tornado genesis. The micaceous vermiculite of dusts is able to adsorb and fix radioactive ions from the air (Syers et al., 1972) as well as nucleate rain and hail. Some of the dust may enter Easterly winds and rain out into the North Pacific Ocean as pelagic sediments and on surface soils of Hawaiian mountain tops, just as do the dusts from Asia coming in on the Westerly winds (Jackson et al., 1971; Clayton et al., 1972).

The dusts collected during the summer of 1974 by the Principal Investigator and NCAR collaborators on Tenerife (Canary Islands), Sal (Cape Verde Islands) and Barbados in the tropical North Atlantic Ocean and from Florida are in the process of being analyzed. Study of the eolian sediment influence on the soils of the North Carolina coast and on Cat Island of the Bahamas was discussed earlier in an indicative report on the Tropical Atlantic dust system (Syers et al., 1969). Analysis of the more extensive set of dusts and comparison to those of the Sahara is underway as part of a study of the long-range dust transport system, which has a role in transport of radioactive materials.

Signature element tracing of dust origin. The concentrations of trace elements in samples of quartz isolated from samples formed at high temperature (igneous) and low temperature (chert) as well as those of mixed sources (soils and dusts from TX, HI, and India) have been determined by instrumental neutron activation to provide an additional check on quartz provenance interpretations. Results for different size fractions shows that the 1 to 10 μm fraction gives the most reproducible results. The concentrations of trace elements, thought to be mainly accessory mineral inclusions, are the same for samples from a single area. Each of the areas studied so far has a distinctive pattern of trace element concentrations that can be used to define geochemical provenance. For example, the samples from Texas and India have concentrations of Fe, Cr, Co, and Sc that are twice those of the Hawaiian samples. The concentrations of Hf in the samples from India (1.8 ppm) are about four times those found for the other samples while the concentrations of Sb in the Texas samples (1.1 ppm) are twice those from Hawaii and India. The concentrations of the rare earths,

U, Th and As are about the same in all of the samples.

The concentrations of trace elements in chert and igneous quartz are similar, but much lower than those found for the soil quartz. An exception is U which has concentrations in chert (about 1.5 ppm) that are about 10 times those of soil quartz and 30 times those of igneous quartz. The data gathered indicates that this type of analysis can be used to assign geochemical provenance and that the results will provide a check on the assignment of quartz provenance as based on oxygen isotope studies.

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Key to COO-1515 Report Series

Contract E(11-1)-1515 of
U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION WITH THE UNIVERSITY OF WISCONSIN

Principal Investigator: Marion L. Jackson

Department of Soil Science, University of Wisconsin, Madison, WI 53706

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COO-1515	Sent		Author, Journal, Content	Manuscript date
	Manu.	Reprint		
1*	x	na	Science Information Exchange form (1965)	15 July 65
2	x	na	Science Information Exchange form (1966)	1 Mar 66
3	x	x	Roth <u>et al.</u> , <u>ISSS</u> , Aberdeen (1967) Verm sesquioxide coatings	1 Oct 66
(4)	x	na	Jackson, Trip Report, Aberdeen	1 Oct 66
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6	x	na	Technical Progress Report (1967)	1 Feb 67
(7)	x	na	Renewal Proposal	14 Feb 67
(8)	x	na	Single Column Budget	14 Feb 67
(9)	x	na	Statement of costs	14 Feb 67
(10)	x	na	Equipment report	14 Feb 68
11	x	na	Science Information Exchange form (1967)	14 Feb 67
12	x	na	Science Information Exchange form (1968)	24 Feb 68
13	x	x	Roth <u>et al.</u> , <u>Israel J. Chem.</u> (1968) Fe coatings/CEC	30 June 67
14	x	x	Jackson, <u>ISSS</u> , Adelaide (1968) pH/CEC	1 July 67
15	x	x	Dolcater <u>et al.</u> , <u>SSSAProc.</u> (1968) CES/mica-verm layer charge	15 Dec 67
16	x	x	Syers <u>et al.</u> , <u>Geo.CA</u> (1968) Quartz Isol/H ₂ SiF ₆	14 Feb 68
17	x	x	Mokma <u>et al.</u> , <u>SSSAProc.</u> (1970) Muscovite flakes/CEC, coatings	27 Feb 70
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24	x	x	Dolcater <u>et al.</u> , <u>Am. Min.</u> (1972) CES	26 Feb 71
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54	x	x	Jackson <u>ISSS</u> (Moscow) (1974) Eolian additions to soils	1 May 73
55	x	x	Sridhar/Jackson <u>SSSAProc.</u> (1974) Verm layer charge decrease	12 Nov 73
56	x	na	Technical Progress Report (1971-74)	29 Apr 74
57	x	na	Science Information Exchange Form (1974)	29 Apr 74

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58*	xx	Henderson <u>et al.</u> , <u>CCM</u> (1976), Verm CaCO ₃ /fixing cations	11 April 75
59	x xx	Sridhar <u>et al.</u> , <u>SSSAJ</u> (1975), Isotopic ratio/source	13 March 75
60		Jackson, Lee, Brown, Chlor-mica ultramicro/elect. mic.	In preparation
61		Lee, Jackson <u>SSSAJ</u> , Fission particle/layer charge	1 May 76
62		Le Roux, Clayton, Jackson, Oxygen isotopic ratio	In preparation
63		Stam, Helmke, Jackson, Neutron activation analysis	In preparation
64		Kinniburgh, Jackson, <u>SSSAJ</u> , Radioactive Ca, Zn, Hg sorp/Fe	" "
65	xx	Jackson, Sayin, Clayton, <u>SSSAJ</u> , H ₂ SiF ₆ reagent/loess	28 Jan 76
66	xx	Clayton, Jackson, Sridhar, <u>GCA</u> , Quartz isotopic resist.	24 Mar 76
67	x na	Technical Progress Report (1975)	27 April 75
68	x na	Science Information Exchange Form (1975)	27 April 75
69		May, Helmke, Jackson, <u>Talanta</u> , ⁵⁹ Fe determ at 0.1 ppb	In preparation
70	x xx	Sayin/Jackson, <u>CCM</u> , SEM cherts	12 Feb 75
71	xx	Jackson, Lee, Helmke, <u>Soil Sci.</u> , U cont. fission tra	4 Mar 76
72	xx	Kinniburgh, Sridhar, Jackson, <u>Battelle Conf.</u> , Zn, Cd sorpt.	1 Sept 75
73	xx na	Technical Progress Report (1976)	26 Apr 76
74	xx na	Science Information Exchange Form (1976)	26 Apr 76
75		Sridhar <u>et al.</u> , <u>SSSAJ</u> , Wind-eroding soils/dust	In preparation
76		Jackson, Clayton <u>et al.</u> , Dusts of tropical Atlantic	" "
77		Gillette, Sridhar <u>et al.</u> , Isotopic tracing of dust	" "
78		Clayton, Jackson <u>et al.</u> , Isotopic mixed reservoir	" "

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EFFORT LEVEL OF PERMANENT PERSONNEL:

Principal Investigator, Marion L. Jackson,

0.25 man-year equivalent, for 12 months (25% of time in year to date, and to end of current term of contract)

Co-Investigator, Philip A. Helmke,

0.15 man-year equivalent, for 12 months (15% of time in year to date, and to end of current term of contract)