FINAL REPORT

Erosion And Transport Of

Eolian Materials On Mars

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The objective of this research was to determine particle longevity on Mars during eolian abrasion. The types of particles used corresponded to what is believed are the most common mineral types that exist on that planet except for quartz; the inclusion of the latter mineral will be explained later. How long will sand sized particles survive when blown about by the high velocity winds which are postulated for Mars? Sagan et al. (1977) believed that sand grains would self-destruct when blown about by those winds; he called them Kamikaze grains, which when translated into Japanese, means appropriately, "divine wind." Experimental evidence suggests that fine particles (of sand size) when used to bombard rock targets, will cause considerable target destruction as well as particle breakage (Greeley et al., 1983). What has not been done is to determine the rate at which particle to particle abrasion occurs. This information, if obtained, bears on the survival of sand sized particles on Mars, the extent to which eolian abrasion can occur on Mars, and whether Martian dunes are composed of coherent, sand sized particles.

Particles colliding with rocks are equivalent to sand moving across a boulder surface, where sand does not predominate; if it did, the sand would bury the boulders. This work, therefore, attempted to simulate a predominantly sand to sand abrasion situation such as might occur on a large sand sea, a barchan or sief type of dune complex. Here, impact of one grain on another has two effects. The first damages the impactor and the impactee. The second involves the movement of the impactee grain by the impactor when the latter arrives from a saltation trajectory; this process not only damages grains, but moves them out of the way, thus transfering kinetic energy to other grains. Grain to grain impact would be expected to be much less damaging than grain to solid impact, which would be the case if one of the grains was fixed. The amount of damage a particle can do is a function of the kinetic energy of that particle, and if the kinetic energy is converted to motion of another particle, then that energy obviously cannot be expended in causing mechanical damage. Thus a good deal of energy is lost in collision which is no longer available for fracture.

Abrasion Chamber

An experimental abrasion chamber was constructed to produce grain to grain impacts and, to as great an extent as possible, to eliminate grain to wall fracture events (Fig. 1). The chamber was essentially two-dimensional in nature; it consisted of a one foot diameter chamber one-half inch deep. At the bottom, two jets emitted high velocity air, and were set at 90° to each other. The particles were entrained by the jets so that they collided at 90°; they then proceeded to fly off into the chamber and eventually returned to the bottom where they were again entrained by the jets. The grains were thus continuously cycled and underwent numerous collisions during each cycle.

The chamber was constructed of wood and plastic; this was a deliberate choice, as it was hoped to minimize particle to wall collisions. There was, however, some minor wall abrasion, but when the grains were run at maximum velocity, there was surprisingly little damage to the apparatus. This indicates that very little particle energy was expended on grain to wall impact; thus most of the energy was funneled into grain to grain impact.

Another way of looking at the wall-particle abrasion situation is that the collisions were essentially low energy as compared to particle to particle contacts. Once the latter type of collision has occurred where the air from the jets meets, much of the collision energy is dissipated in grain fracture or intereference in particle paths. By the time the grains reach the chamber wall, they are traveling at fairly low velocities.

Velocities were determined by allowing particles to fall into a jet of air in the same manner as in the apparatus. An optical rotating device was placed next to the particle stream. During experimentation when the particles appeared to be stationary in the mirror, the optical system and the particle speed were synchronized. Since the rotational speed of the mirror was known, the speed of the particles could be determined. This is a well established technique for determining velocity and is used in various other applications. It also appears to give reproducible results, and is a valid way of determining particle velocity. The velocities measured are thus velocities within the jets, in other words, absolute particle velocity and not collision velocity. The latter is the relative approach velocity of the particles.

It would be interesting to determine how many impacts each grain sustained, but this is impossible at present with the equipment available. The grains were probably subjected to at least one high velocity impact/cycle, in addition to several lower velocity impacts.

There is a calibration mean particle velocity for the apparatus, although one cannot speak about a mean particle velocity. Essentially maximum particle velocity for the system can be measured, and we know that the velocity will range from maximum all the way to zero. Given the manner in which the particles behave in a jet stream which has a Gaussian distribution, and given that they will collide randomly in the chamber, it is probably safe to conclude that they have a normal distribution. Thus most collisions have a velocity which is half the maximum velocity.

This is reasonable as far as the experiments are concerned, as if one considers a saltation cloud of particles and looks at the velocities within, an average or mean particle velocity and a maximum velocity can be defined. At any one time, a very small number of particles will be achieving that maximum velocity; most will be traveling at some lesser velocity which will be approximately one-half maximum. If grains traveling in desert environments are considered, and not just at any instant in time, every single grain in that system will experience that maximum velocity. Grains at lesser velocities will do lesser damage. What we are really asking is that if grains achieve maximum velocity, will they destroy themselves in Kamikaze fashion?

Materials Used

Quartz, basalt, olivine and volcanic ash were used as abrasion materials; quartz was selected, as we have had a good deal of experience with the way it reacts to abrasion (Greeley et al., 1983; Krinsley et al., 1979), while the others are believed to occur in large quantities on Mars. Quartz was used as a control, although there is no reason to believe that it occurs in large quantities on that planet. The basaltic material is relatively hard and compact and thus represented an excellent material for abrasion tests. Olivine is also a relatively hard material. The pyroclastics were extremely fragile; 99 percent of the material was vesicular, while the remainder consisted of lithic fragments and some crystals. Quartz, olivine and basalt were crushed mechnically and sieved to between 710 and 1000 microns. The pyroclastics were 1 to 2 mm (1000 to 2000 mμ) in diameter; the size was reasonably close to that of the other three materials, but unfortunately, the 710 to 1000 micron size could not be obtained.

Results

Table one gives the various abrasion velocities, measured velocity of particles, calculated velocity of collision, time during which abrasion took place, the charge (material) in grams, the amount that remained after the experiment was completed in grams and finally, the percent remaining after completion. As far as quartz is concerned, it is destroyed at the highest velocity; most of the dimmunition occurred in the first few minutes. Once the material starts to destroy itself, there is less material in the system, and the number of collisions drops markedly, and as time progresses, the surviving grains have better and better chances of survival. The remaining weight will diminish at an exceedingly slow rate. When the lower quartz velocity experiments are studied, it is clear that as velocity is reduced, the material survives a great deal longer. This is not unexpected; however, at Martian velocities, quartz will destroy itself, although it may take somewhat longer at lower velocities. Basalt appears to be more resistant than quartz, which is a surprise as the latter is harder than basalt. However, it may be that brittleness is a problem as far as quartz is concerned; basalt may be less brittle than quartz. In any case, basalt will self-destruct almost as rapidly as quartz and in any case, very little basalt will remain in the sand sized range after a few hours.

Although only one run was made with olivine, it follows the same pattern, and as a matter of fact, is less resistant to abrasion than either basalt or quartz. Pyroclastics were run only once, but once more, destruction is quite rapid. As might be expected, pyroclastic material, because it is so weak, is destroyed faster than other materials.

The initial quantities varied; they were manipulated to provide a fairly constant flux within the chamber at all times. An attempt was made to maintain the same density of material between the jets. In addition, electrostatic charging was a problem, and the proper amount of material had to be selected so that breakage was able to proceed.

Discussion

These tests show that if particles of sand size are moved at velocities which presumably occur on Mars, they will be destroyed over extremely short time periods, which geologically represent essentially no time at all. Thus grain to rock collisions are not necessary for this type of destruction to occur.

The experiments used very coarse materials. Destruction was so rapid, that the particles had no time to round. One hundred micron particles might react differently to abrasion. However, even supposing smaller particles and lower velocities, rapid enough destruction occurs to deplete the sand reservoir in a short time geologically. And yet we know that there are extensive dune fields on Mars; if the particles or sand self-destructs over short geological time periods, there should be insufficient sand sized particles to permit the formation of dune fields such as exist around the north polar cap of Mars.

Although the experiments were not run at Martian pressures, previous work has indicated that mechanical eolian abrasion acts in the same manner at both Earth and Martian pressures. However, under low atmospheric pressure (several millibars), abrasion occurs somewhat more rapidly (Krinsley et al., 1976). Thus abrasion on Mars should produce more fracturing than on Earth, given the same wind velocities. This, of course, would increase the "Kamikaze effect."

How is it possible to account for this dichotomy? In the experiments described above, electrostatic charging interfered with the process of abrasion; just the right weight of particles was necessary so that the experiment could proceed. If there is a very narrow particle density at which sand sized particles can fracture, this would increase the sand reservoir. In addition, Greeley et al. (1983) have shown that the amount of particle abrasion is very low on Mars and could have been quite low for a considerable period of time. They suggest that electrostatic aggregates could have formed on that planet and perhaps could be responsible for the sand that forms dunes on Mars (see Greeley, 1979; Krinsley and Leach, 1981). There are other possibilities: particles on Mars may move at lower velocities than we suppose, or they may move at the velocities postulated, but may not move as often as suspected.

It is possible that abrading particles of 100 microns or so in the above device might produce considerably less abrasion, but Krinsley et al. (1979) ran particles about this size in an abrasion device and produced fracturing of roughly the same degree at similar velocities and time periods, so that abrasion of smaller particles would not solve the problem. In addition, evidence suggests that densities in the specimen chamber are about those of a typical sandstorm on Earth, and even if these densities are off by an order of magnitude for Mars, the problem still remains.

Thus, to summarize, the tests conducted show that if coarse sand sized particles of the composition presumably present on Mars are moved at the wind velocities indicated above, almost complete destruction will occur in time periods insignificant geologically. These events will occur on the order of hours. Grain to rock collisions are not necessary for almost complete destruction; grain to grain collisions are sufficient. A number of explanations are suggested, but evidence is not available to prove or disprove any of them. The only way to conclusively solve the problem is to examine sample returns from Mars.

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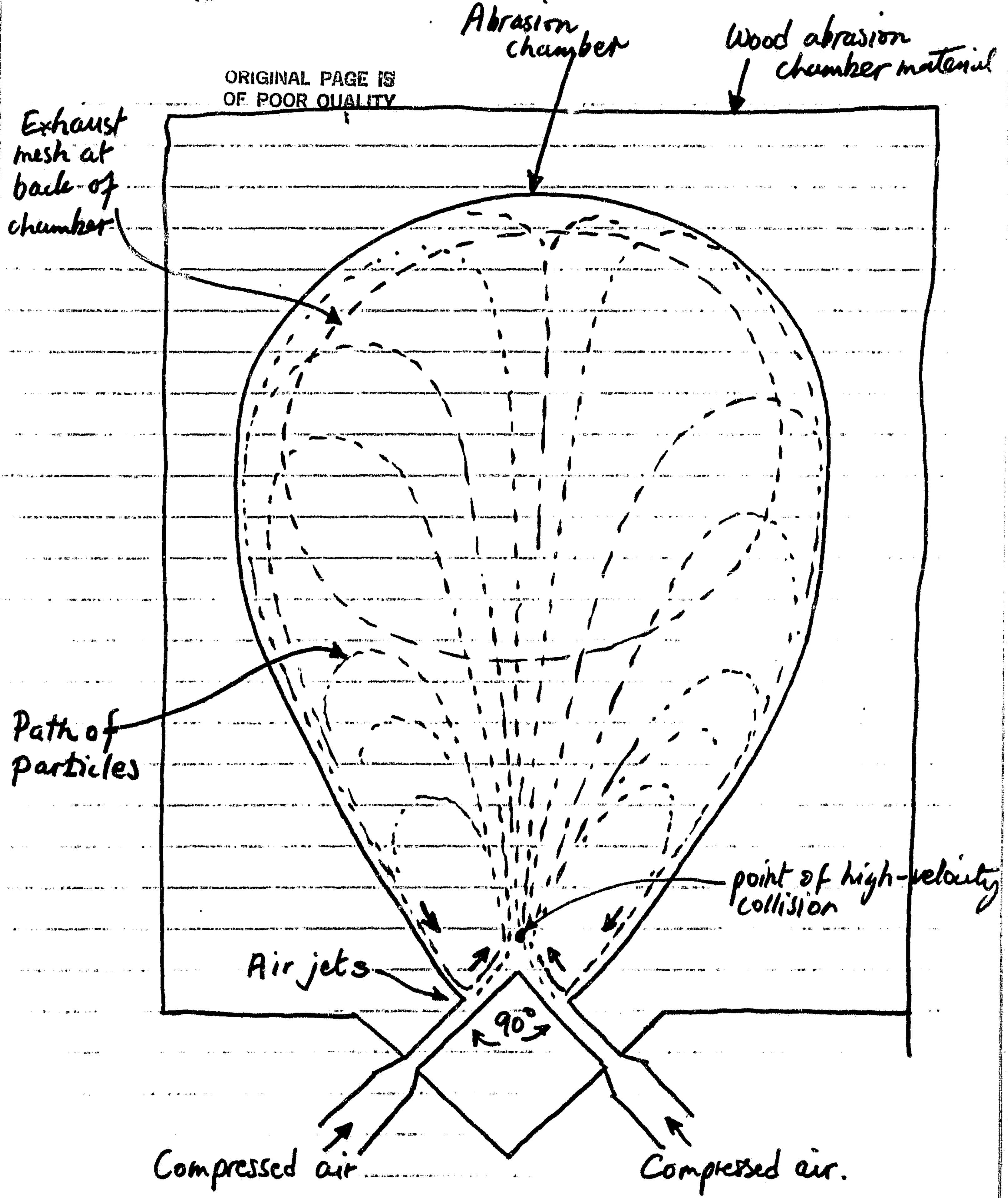

Figure 1.

Quartz

Time (Hrs)	Starting Wt. (Charge in Grams)	V_p Particle Velocity m/s	V_c Collision Vel. m/s	Remaining Weight (gms)	Remaining %
1	40	47	66	1.7	4.25
1	20	32	45	5.7	28.5
2	17	25	35	5.1	30
1	15	20	28	10.0	67
4	15	17	24	9.1	60.1

Basalt

1	39	47	66	7	18
3.42	39	47	66	2	5
1	35	41	60	11	31
1	35	25	35	26	74
1	15	13	18	13.7	91

Olivine

1	40	47	66	0.8	2

Pyroclastics

0.5	40	47	66	<0.2	<0.5

Table 1.

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Addendum to Final Report: Erosion and Transport of Eolian Materials on Mars.

David Krinsley

NAGW 24, Supplement 03

Backscattered electron techniques in scanning electron microscopy have been applied to the study of mudrocks. A number of detailed studies have done on Lower Jurassic mudrocks; additional examination has been made of a wide range of shale samples. For the first time, it is possible to study the relationship between the various grains in mudrock thin sections; the diagenetic relations and period of formation of the various clay minerals, quartz and pyrite have been determined. The technique could be applied at some future time to the return of samples from planetary bodies and presently to the study of lunar rocks and meteorites. As a matter of fact the technique is valuable for the study of any kind of fine grained material. These studies will be the basis for a new mudrock and fine grained rock petrology.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
RESEARCH AND TECHNOLOGY RESUME

1. DATE PREPARED	April 5, 1983
2. TITLE	Erosion And Transport Of Eolian Materials On Mars
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3. NUMBER/CODE b. CURRENT	
4. PERFORMING ORGANIZATION	Dept. of Geology Arizona State University Tempe, AZ 85287
5. CONTRACT/GRANT NO.	
6. DATE a. STARTING	
6. DATE b. ANNIVERSARY	
7. INVESTIGATOR'S NAME / TEL. NO.	David Krinsley 602-965-2813
8. NASA ALT. TECH MONITOR'S NAME / TEL. NO.	
9. INSTITUTION CATEGORY CODE	UN

FISCAL YEAR	STATUS a.	MANPOWER (MY) IN-HOUSE b.	S/C c.	IMS d.	FUNDING (In K) R/D e.	TOTAL f.
10. PRIOR						
11. CURRENT						
12. BUDGET						

13. DESCRIPTION *(a. Brief statement on strategy of investigation; b. Progress and accomplishments of prior year; c. What will be accomplished this year, as well as how and why; and d. Summary bibliography)*

a. Objectives: It is intended to determine quantitatively the degree to which size reduction occurs during the eolian transport of sand sized mafic material. These materials presumably exist on Mars, and the amount of size reduction indicated by laboratory studies may provide a general idea as to the survivability of the various mafics during eolian abrsion. More specifically, it may be possible to eliminate certain mafic minerals and/or glasses as candidates for sand in the Martian dunes.

b. Progress: Crushed sand sized particles of volcanic glass, basalt, olivine, pyroxene, plagioclase feldspar and quartz (as a standard) have been prepared for abrasion. A new eolian abrasion device has been constructed and modified to simulate Martian eolian abrasion. It consists of a 500 ml abrasion chamber of glass, in which 10 grams of crushed sand are placed; mobilization is achieved by air jets from a compressed air/regulator filtration system. The surface textures of the grains abraded are absolutely identical to naturally abraded grains. The behavior of the grains remains constant at all velocities; the device can handle particles between 100 and 5000 microns. Texts on the various minerals are now underway and will be completed soon.

During examination of quartz and basalt in thin section with the scanning electron microscope (SEM), a new technique, backscatter electron microscopy (BSE) was adapted to study basalt and mudrocks. The method produces atomic number contrast (Z) and simulated three dimensional topography. The Z contrast permits individual minerals to be distinguished, as differences in gray level are related to chemical composition. Petrographers for the first time will be able to examine mudrocks in the same manner as sandstones and carbonates are studied.

c. Proposed work: 1. Complete abrasion studies and examine results as related to survivability of particles. 2. Continue to study mudrocks and other fine grained rocks with backscattered electrons in scanning electron microscopy.

d. Summary Bibliography (FY 82-83): 2 extended abstracts (2 coauthored) and 2 papers.

e. Personnel: One faculty (part time).

	TYPED NAME AND SIGNATURE	DATE
TECHNICAL MONITOR	Joseph M. Boyce	
APPROVING OFFICIAL		

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Krinsley, D.H. and Marshall, J.R. 1982. Particle attrition device for Earth and Mars. Repts. Planet. Geol. Program 1982-83, NASATM 85127, 408.

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Semiannual Status Report-NAGW 24, Suppl. 03   David H. Krinsley 6/20/83

An eolian abrasion device has been used to determine the susceptibility of quartz and mafic sand sized particles to eolian transport, in order to simulate eolian action on Mars. The device was described in my last semi-annual report. The experiments have just been concluded and the following information is available; it will be written up for publication.

1. Particles in the device self-destruct at velocities above about 30m/sec. This information suggests that, given high velocities and a high concentration of particles such as occurs during sandstorms, a great deal of silt and clay will be produced rather rapidly. This material, and particularly the clay, would then be spread over the planet by the prevailing winds.

2. The material produced is highly electrostatically charged; since the particles are small, the hypothesis that aggregates are present on Mars is quite likely.

3. The distribution of the particles produced is bimodal; this fact is in agreement with the distribution of grains found on the Martian surface by the Viking Lander.

4. Basalt grains seem to withstand abrasion to a greater degree than quartz, which is unexpected. Perhaps this is because quartz is more brittle than basalt.

In addition, as noted in my last semi-annual report, backscattered electron techniques in scanning electron microscopy have been used to study mudrocks. A number of detailed studies have been done on the Lower Jurassic Yorkshire mudrocks at Whitby, UK. For the first time, it is possible to study the relationship between the various grains in mudstone thinsections; the diagenetic relations and period of formation of the various clay minerals, quartz, and pyrite have been determined. These studies should be the basis for a new "shale petrology."

Semiannual Status Report Bibliography-NAGW 24, Suppl. 03   David H. Krinsley

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