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BENEFITS OF SPACE RESEARCH TO THE NATURAL SCIENCES

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I want to begin with the problems that have to do with the practical applications of the studies of the moon. "Are we really on the planet best suited for the human species?" If you ask this question seriously, the answer that suggests itself is that perhaps we are not. As you know, the body plan that we all share here is that of a rather small monkey, sort of bent forward. In this creature most of the soft parts were slung from the backbone where it would be natural, like a suspension bridge. In putting the thing in the erect posture and increasing the mass a great deal, these parts sort of slope down, like a bunch of sacks hung from a vertical pole. It does not work very well. It works, I assure you, progressively worse as you grow older. This is a source of a lot of our bodily difficulties — flat feet, varicose veins, hemorrhoids, and several other things. What I suggest is that a lot of this trouble comes from the fact that we are on a planet on which the force of gravity is stronger than that which would be best suited for creatures built the way we are. Ultimately, the agony of childbirth stems also from this fact. We are trapped in this situation by the rather large force of gravity of the planet that we live on. So I want to suggest that eventually we may find it to our advantage to shift to a planet where the force of gravity is less, and where we do not have this painful problem.

In our office we have been doing some work on the surface of the moon, and Adler has been doing some work on it. One of his ideas concerned an apparatus of about the size of a flat iron which would direct alpha particles down at the lunar surface. Some X-rays would come back, and he would analyze them to find out of what the lunar surface was composed. He never could get approval for that, but, with the aid of Dr. Giacconi, he discovered that the sun sends energetic X-rays down which generate other X-rays, which are characteristic of the lunar surface. In this way he was able to analyze the whole thing by using the sun instead of his apparatus. A great deal of work has been done by this method in analyzing the lunar surface. He has thought that the back side of the moon is mostly anorthosite, something like the Adirondacks. The front side of the moon is confirmed, but everybody thought that there were basalts everywhere. But the most striking thing is that he never seems to find any large amounts of magnesium. The inside of the moon has got to be magnesium, not pure magnesium, but MgO and magnesium silicate, Mg_2SiO_4 or $MgSiO_3$. The point is that it has to be made largely of MgO. We have been told that the maria, the great black spots on the moon, are places where meteorites came down and eviscerated the moon, got the guts out, and spread them on the outside. So we should have areas on the moon that are covered with MgO, large amounts of it. But we do not find it; therefore, something is radically wrong.

As you know, right now the almighty dollar is having the worst time since the days of George Washington, when they papered the walls with them. The value of the dollar, in terms of gold, is dropping. This is because of the fact that we are having an excess of imports over exports; we are not making money as a country; the nation as a whole has a net outflow of gold, and that is making trouble for us. It is this trouble, devices that have been developed in the Lunar Program — electronic control devices or computers, both of which were an important part of the satellite program — which are the kinds of things that are now earning us dollars. Those are among the important exports which are not being balanced by corresponding imports. In other words, the U.S. computer industry is earning dollars for the U.S. and is helping us in this dollar crisis. All the other space-related hardware is also earning us money because we have a net of import balance on it. In the hardest, coldest, bloodiest sort of sense, the dollar is being held up by the space industry. You cannot get much more practical than that!

A second field of effort which we have been involved in is the study of impact metamorphism. I will tell this story because I got mixed up in it, not very much, but I was involved in it. About 15 years ago, I went to dinner with Shoemaker out at Ames. We were talking about tektites, of course. Shoemaker handed me a little chunk of rock, rather roundish, and he said, "If tektites come from the moon, you should see things like that, because that is what we found in a meteorite crater and it looks like what would be thrown out." So I took the thing back. Being an astronomer, I handed it to Paul Lowman, geologist, and said, "Shoemaker says if we ever get anything from the moon it will look like this, because this was thrown out of a meteor crater." Lowman sliced it and looked at the thing under a microscope, the way they do. Then he sent the thing over to the U.S. Geological Survey (USGS), because there was something that he did not understand. The U.S. Geological Survey analyzed it by X-ray and they found coesite in it. A little later a fellow from the USGS came over to see me, and he said, "Do you know what coesite is?" "No," I said. He said, "Well, let me explain it. It is a high-pressure polymorph, a high-pressure form of quartz, produced, evidently, by the impact." So I went around to see one of the fellows in my office named McDonald, Gordon McDonald, and asked, "Gordon, do you know what coesite is?" He answered, "Yes, I do." It turned out that he had been looking for coesite in the rocks of the earth for about 7 years and had never found it. This is an effort directly supported by the space effort. We look at this thing, because we were trying to study the moon. But that is not the end of the story.

The first result of the coesite discovery was that we now had a tool by which we could recognize impact craters. Coesite is produced by impact. It is a high-pressure form that takes 16 kilobars. You cannot get that kind of pressure on the earth, except at great depths. The astounding thing was that once the mineral had been recognized, they went out to the meteor crater and found this unknown mineral in carload lots around there. In places it was about 7 percent of the rock. Imagine, an unknown mineral in a well-studied site, available in carload lots! They discovered another mineral, stishorite, in the same place, also formed by high pressure, but this was only available in about 1 percent of the rock. Now with these two minerals, they went to all kinds of places. Shoemaker went to a church in Nördlingen, Germany, on the way to an international congress. The walls of the edifice looked like meteor crater material, so he got a piece from a quarry nearby, sent it back to the USGS; it showed coesite in it. Shoemaker walked into the International Geological Congress and said that this crater — which is some 25 km across, with a whole city sitting inside of it — is the result of a meteorite impact on the surface of the earth. Professor Wagner of Tübingen said, "I have gone over the Rieskessel for 55 years and nobody can pick up a single rock on a Sunday afternoon and tell me what the Rieskessel is." But he was wrong; that is exactly what had happened. What has come out of that beyond this, is the following: There has been a tremendous effort in the study of impact formations of all kinds. We have discovered about 60 impact craters across the world and mineralogically identified them as being of this kind. In addition, De Carli and Jamison in the U.S. said that there are diamonds in the meteor craters, in the irons. And Nininger had stated that those diamonds were probably because of shock. His reasoning was, "If coesite is made from quartz by shock, maybe diamonds can be made from graphite by shock." They got together, and according to De Carli's story as he told me, he took a barrel of water and about as much graphite as it takes to make a lead pencil, and 1 lb of gun powder and made diamonds out of it. These diamonds were very tiny, so tiny that they could not even be used as an abrasive. Recently, we have discovered how to sinter them so they can now be used as an abrasive. By this method, diamonds were produced in pound quantity. It is a new industrial process which will eventually be of great importance. My cousin's wife came out to visit me from Stanford Research Institute a while ago, trying to figure out how she could sell these diamonds for any reasonable purpose. They are so fine that at the time the only thing they could think of was to paint them on the outside of automobiles so that they would not scratch.

Another thing that came out of it was that Harold Urey had a theory which is called "Diamonds, Meteorites, and The Origin of the Solar System." It is published in the Astrophysical Journal, 1950 or thereabouts. The basic idea of this theory was that there are diamonds in the meteorites. This means that the meteorites had to be under great pressure when they were formed. The only way to put them under great pressure was to put them in a center of a body, a large planet. The planet had to be as big as the moon, and therefore, this theory was that the whole solar system was composed of objects which once had been moon size and had been broken down to form the solar system and then rebuilt to make the planets. Well, our idea collapsed because now that we had the coesite, it was clear that shock can make these high pressure polymorphs, like diamonds. There were no grounds to assume any longer that the meteorites had ever been inside very big objects. There was a battle about this issue that lasted about 4 to 5 years. The conclusion was just as I have stated, there is no reason to assume that the solar system was formed this way.

There is another implication. We went out to look at Sudbury. Bob Dietz had been there, and had found some queer looking things around Sudbury called shadowcones. The shadowcones are supposed to be from meteorite impact. So Dietz had suggested back in 1950 that the Sudbury feature was produced by a meteorite impact. Bevan French went out there in my place because he did not believe what Dietz had said, but he came back a believer; he found, in the Sudbury material, not coesite, but some of the other marks of impact metamorphism. I should say that in the 4 or 5 years between the discovery of coesite and the time when French went to look at Sudbury, there had been a tremendous development of this scientific impact metamorphism — not only with coesite, but also with quartz, and especially with Tübingen, in Germany — a development in which they saw planar features in quartz, which are marks of impact metamorphism. So French came back and he identified the Sudbury structure as an impact structure. He has now convinced the other students of Sudbury (and there are some people who study Sudbury with a good deal of enthusiasm) that it is impact. The reason why people study Sudbury with such enthusiasm is that 75 percent of the free world's nickel comes from Sudbury. It is one of the world's greatest mining sites. Sudbury is 25 percent of the mineral wealth of Canada, and the backbone of the International Nickel Company. Billions of dollars have already been taken out of it. So you cannot really claim that information on how such structures are formed is not of considerable practical importance!

We have already discussed the implications of this new science which began — I point out again — as a study directed toward the moon. The whole interesting field of impact metamorphism came out of the lunar study. Until very recently, we have not had actual lunar samples to deal with. We had been thinking about what they would be — we have actually had to think about what the samples would look like, to plan for them. It is out of this planning that this wonderful new work has come.

How does research of this type tie in with cosmology? In the moon there were once tiny blips of nickel iron, which have since disappeared. In the earth, we know where they went; they went to its core. But the problem of problems with respect to the moon is, where is the moon's nickel? Nickel is one of the siderophiles; you would never purchase a nickel ring. Gold and platinum are also gone. Where did they go, where did the siderophile elements of the moon go? The most logical and obvious answer is that they went down to the core of the earth, and the moon is formed from the outer mantle of the earth. I have done some mathematical developments which show that you can make this theory stand up and walk. Thus, through these studies of the moon, we are working backward toward the origin of the solar system. I believe this process of fission, the formation of the moon from the earth, is fundamental to the way in which the solar system itself was formed. Perhaps we can participate in this enormous intellectual adventure that Dr. Giacconi was talking about, in which we study the beginnings of things, both through X-ray astronomy and also through the study of the rocks which lie about us everywhere. If we really look back at the history of cosmology, we see that a key point in it, one that astronomers never acknowledge, was in 1948 or 1949 when Patterson and Urey showed that the earth must be 4.5 billion years old. The astronomers went back and had a quick look at their figures and recalculated the distance scale based upon the Cepheid variables. Everything got switched around and suddenly the universe became a good deal older than 4.5 billion years. That was one of the hard facts — the hinge on which the whole thing turns. Geology can give you hard facts which are mighty useful in the welter of beautiful new results of the type that Giacconi was talking about. You do need a few things that you can absolutely bet on.

Recently, the meteorite people have shown that at the time when the meteorites were formed, there had just been a supernova or something like that — something had produced enormous amounts of fresh nuclear materials, because there was radioactive iodine-129 and radioactive plutonium-124 in the meteorites when they were formed. Which means that 4.5 billion years ago, within a few hundred million years before that — say 4.7 billion years ago, but not earlier than 4.8 billion years ago — there was some kind of a nuclear event producing radioactive material in the immediate vicinity of the solar system, a part of which reached the earth. Thus, when you get the geological background, the rock background, you get a lock of a different kind; a lock that will not be fitted by just any key but only by the right key. So there are two kinds of things that are needed: We need these diffuse observations, and we also need the very hard results that come out of hard-rock studies, because they finally define the thing.

In conclusion, these are some of the things that we hope to get out of the space program. We hope to get new techniques and new devices which will partly support our dollar and partly tell us things about the moon. We hope to see deeper into the origin of the moon, and with it, the origin of the solar system. Eventually, we hope to be able to look back to this event which is at the beginning of the solar system and back toward these fascinating cosmological things that Dr. Giacconi has been talking about.

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