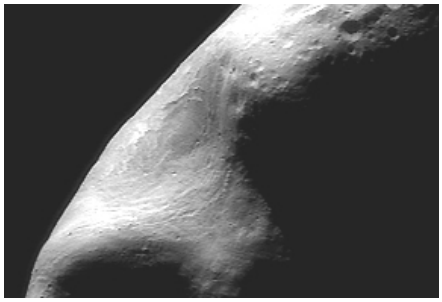
Is 433 Eros Asteroid Younger Than Expected?



February 15, 2000 photograph while the NEAR satellite was passing directly over the large gouge "saddle" that is surprisingly smooth and free of craters. Detail down to 120 feet (35 meters) across. Narrow parallel troughs closely follow the shape of the saddle gouge. Photograph courtesy Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland.

Earthfiles, news category.

February 27, 2000 Laurel, Maryland - A human machine is orbiting an asteroid for the first time in known human history. It's a NASA satellite called NEAR for Near Earth Asteroid Rendezvous. NEAR moved into orbit around an asteroid called 433 Eros on February 14th. At first the NEAR satellite was photographing at a range of 210 miles. But this past week on February 23rd, NEAR moved into about 130 miles from Eros. The satellite will keep getting closer to the asteroid over the next 12 months until its mission is completed in February 2001.

The goals are:

- To measure the big rock's size, shape, mass and gravitational field.
- To determine the elemental and mineral composition across its surface.
- To map the asteroid with an imaging camera and a laser range finder to make topographic map.
- To measure the magnetic field and to study the asteroid's interaction with the solar wind.

NEAR satellite image of 433 Eros asteroid on February 17, 2000. Eros is 21 miles long, eight miles wide and resembles a Dutch wooden shoe from some angles. Photograph courtesy JHUAPL.

This color image of Eros was acquired by NEAR's multi-spectral imager on February 12, 2000 at a range of 1100 miles (1800 kilometers). It is part of the final approach imaging sequence prior to orbit insertion. The color is close to what the unaided human eye would see. The butterscotch hue is typical of a wide variety of minerals thought to be major components of asteroids such as Eros. Photograph courtesy of JHUAPL.

In fact, where the heel curves out like a saddle, images reveal a surprisingly smooth surface that has scientists puzzled. This week I talked with Dr. Lucy McFadden, Geophysicist and Senior Scientist in the Dept. of Astronomy at the Univ. of Maryland about the question: Is 433 Eros younger than expected?

Interview:

Lucy McFadden, Ph. D., Geophysicist and Senior Scientist in the Dept. of Astronomy at the Univ. of Maryland, College Park, Maryland: "We don't know yet whether that saddle area is a very large crater? Or is it something that appears bowl-shaped by some other process? And that's one of the questions we are going to be debating in our science team meetings over the next coming weeks. But nevertheless, this saddle area does not have many craters in it which means it is a relatively recent phenomenon. And it would be very unusual to have a crater that large produced in recent time.

I think I need to inject here that most of the cratering in the solar system occurred in the first billion years of the solar system. There is a period on the moon there is a period in solar system history that we call Late Bombardment. And it's a time when there were still a lot of small objects in orbit around the sun and there were a lot of collisions just when the planets were forming and debris was being swept up. And so there was this phase when planets were really battered by lots of impacts. There's evidence on the moon and the fact that we can date the rocks on the moon and we show that the cratering trailed off after the first billion years of the solar system.

Is it fair to say that we still don't precisely understand why the asteroid belt is there? Hypotheses over the years have suggested there might have been either a small planetary body or moon-like body that some how got torn apart either in collision or by the gravitational forces of Jupiter.

We actually are confident in our simulations. And we can only do computer simulations for the formation of the solar system back billions of years ago. But we can simulate the fact that the gravitational force of Jupiter which is extremely massive and therefore, a powerful gravitational force, actually prevented a planet from forming. So, it is not that there once was a planet there and it broke up, but the gravitational forces between Jupiter and the Sun prevented a larger planet from forming.

Then Mars is as far out as another planet could have formed between the earth and Jupiter?

Right. Well, actually, the largest asteroid, Ceres, does lie where a planet would form. But it never grew to big enough size. The Jupiter/Sun forces and gravitational interplay of the other planets kept Ceres from growing larger. And Ceres is about a thousand kilometers in diameter or about a third the size of our moon. So, there is something there, but we don't call it a planet.

Eros, in terms of a broken up piece of asteroid rock, is one of the bigger ones in the orbit between Mars and Jupiter, correct?

It's one of the bigger ones that crosses inside the orbit of Mars and comes toward the earth. When we're trying to create our scenario of why is Eros a younger surface than the other asteroids and why what does the cratering density on Eros tell us we have to keep in mind that Eros currently leaves the main belt and comes inside the orbit of Mars and approaches the earth. But that orbit is not a stable orbit. That's not something that Eros has done for the whole life time of the solar system. It is something that it has done for only millions of years. What record, what part of our cratering record is due to the past million years? Or in the past millions of years? Probably not much, but we do have to ask ourselves or remind ourselves that Eros has not always been in the main asteroid belt and was in the inner parts of the main asteroid belt. So maybe that's why it's a younger surface than the asteroids Ida and Gasper which the spacecraft Galileo has flown past.

Meaning that if it had been in the inner part of the asteroid belt, it might have been protected by outer asteroids and therefore not hit as much?

That could be possible. You know, I really don't know the answer. I can't figure out why. It's not clear to me at this point. And this is one of the issues we're looking into. Why should the inner belt asteroids be younger? Although there is one hypothesis that is complete speculation at this point.

There is talk that the sun went through an early phase in which it got a lot brighter. And if it got brighter, it was producing more energy and then the inner part of the solar system would be hotter. And so maybe that heating affected the surface and sort of reset the clock. If there was some volcanic activity that affected the inner belt asteroids but did not affect the main belt asteroids. That would erase some of the bombardment history.

So, there could have been volcanic activity on the asteroids themselves?

Yes. And what I'm saying in this speculation is that the heating, the heat source for this volcanic energy, was not internal like it is on the earth.

Like a melting?

Yes, it was induced by high temperatures melting the surface inward.

From the sun being brighter and hotter?

Exactly. Now, this is complete speculation. It's a crazy idea. We haven't had this discussion in the science team yet about whether that's feasible.

But the fact is that there is a mystery about why 433 Eros should have some smooth regions that suggest that it's younger?

That's right.

Unless there was some melting or something else. This goes to the question: why should it have this erratic and unstable orbit?

I think that's just sort of the luck of the draw. There are a lot of gravitational interactions. There are gravitational interactions among all the planets in the solar system. And there are regions in between Mars and Jupiter that have been swept clean of asteroids. And if Eros was near one of those regions, it could have been knocked out and had its orbit changed.

Asteroids are swept out by that huge gravitational dynamic with Jupiter?

Yes. And that sends them out of an orbit that's in one region of the asteroid belt and there are small changes that added up over billions of years result in significant changes in the shape of the orbits.

Any computer projections into the future or distant future in which Eros could actually impact with earth?

We have done, the dynamicist the people who do this we call them dynamicists because they study the dynamics of the motions of objects in the solar system they have modeled the affects of gravitational changes on the orbit for ten to twenty million years into the future. And with those, we are limited by availability of computer time. None of those changes for the next 20 million years is going to yield an earth-crossing orbit for Eros.

Well, that's the good news.

That's the good news. We don't have to worry about that.

Are there any others out there lurking or could suddenly be hit by something else and sent our way?

Not for the asteroids we know of and we can model their orbits forward in time we do that first when we discover them for a short time period like 200 years. And there are none that are going to hit that we know of in the next 200 years.

The unknown, unpredictable part is whether something could come through the solar system like a new comet and hit an asteroid which deflects its path, possibly even toward earth?

Right. But you have to keep in mind that in the scale of solar systems, the earth just covers a small percentage of area that a comet can travel through. And we do we've seen in the past couple of years we've had spectacular bright comets come through the inner solar system such as Hale Bopp and others in the past couple of years and we didn't know about them until a year before they came to their greatest brightness. Well, Hale-Bopp we knew about four years in advance. But it's not very likely that something will come on collision course with us. The probability is extremely low. It is possible. But when you look at the area of the solar system that comets travel through and you compare that area to the area the earth sweeps out in its orbit, it's a very small fraction. And therefore, the probability is very low.

But unpredictable asteroid deflection to an earth-crossing orbit is a NASA concern, right?

Yes. In recent years, NASA has picked up the hazard mitigation as one of its concerns. So, that is part of it. But let me comment on something being hit and having its orbit changed. Again, we know what's in the near vicinity of earth. And again, the probabilities of collisions in the solar system is very small. Most of the a material has been swept up already. What remains is small things that do do some damage. Meteorites fall to the earth all the time. And a couple of years ago, a meteorite fell to the earth and was seen along the eastern seaboard on a Friday night and many people were at football games and saw a large meteor trail and the rock actually ended up in Peekskill, New York and dented the back of a car. So they do do damage, but they are mostly small things.

We didn't know about that meteorite, but we are confident that there aren't a lot of large things that can do regional damage. And then when there are collisions in space, the transfer of energy is such that the change in the orbit is small. So, there really is no concern from one collision all of a sudden nudging something into an earth-crossing path. Because again, we know what's around us. If we had to worry about that, we'd know about it.

But, but, nevertheless, we are watching. And the consequences could be so extreme that it is worth NASA's vigilance to survey and catalog what is out there. So, we are keeping a constant watch.

Because there is also some mystery about where all the water on Mars went, is it possible that at one point there might have been something large like a comet or a body that came through the solar system and hit Mars, causing a break up? Some of the asteroid material could be from Mars or a foreign body that came through the solar system and collided with Mars?

Oh, I see what you are saying. So that some of these asteroids might be ejecta from Mars?

Yes, from Mars, or from a comet or asteroid coming through the solar system.

That is possible. Except in the case of Eros, our computer models - which don't prove anything but give our most likely scenario - is that Eros evolved from the inner part of the asteroid belt. It's not possible to trace Eros back to Mars. However, we do have samples from Mars in the form of what is called the Snick meteorites and there are indeed meteorites that have come from the moon. So, it is conceptually possible. But again, they are small fragments.

I understand from talking to a meteorite specialist at Arizona State University in Tempe that the difference between a Mars or moon meteorite has to do with the amount of uranium and potassium. Planetary geologists consider those to be a marker. I'm curious if you can do spectroscopy of Eros from the orbiting satellite?

Ah, very good question. Well, yes and no. Yes and maybe. The NEAR spacecraft has six science instruments on board and one of them is called a gamma ray and x-ray spectrometer. And that instrument, that spectrometer, will be measuring the abundance of it won't get uranium. Will it get potassium? I don't think it is going to get either of those elements

Studying composition might help answer whether or not Eros could have originated on Mars.

Right. Right. Conceptually, yes. However, when we study the meteorites they are measuring very small amounts and making very precise measurements of the uranium and potassium. And they are getting ages. They are measuring the isotopes of those from high precision laboratory measurements. And the remote sensing instruments on the NEAR spacecraft are not going to give us the necessary precision or measure the necessary isotopes to make that distinction.

In terms of the composition, the elemental composition from the X-ray and gamma ray spectrometer the first thing we want to do, the first thing we look at on the NEAR mission is the magnesium and silicon ratios and the ratio of irons to silicates which are fundamental ratios that the gamma ray spectrometer and x-ray spectrometer can measure and we already have a plot of those ratios and where the different meteorite types land.

Why those particular elements?

Those are the ones with the energy of the gamma ray the gamma ray spectrometer measures let's see, there are gamma rays that hit Eros from cosmic rays. The energy source is cosmic ray particles. And they hit the surface and the

electronic process there's a resonance process that emits elements at a certain frequency that is characteristic it emits gamma ray and x-ray emission at a certain frequency that is characteristic of the elements. And it's the physics and the design of the instruments that can detect these emissions that are due to magnesium and silicate and iron and there is a suite we can also measure aluminum. I just don't think we can get the uranium and potassium. I have a chart downstairs, but it's not I've listened to people brief me on this, team members that are working on that instrument. This is not my instrument specialty.

It would be something if scientists could confirm that one of the asteroids came off Mars.

Right. But the approach that we prefer to take what is easier for us than developing these instruments that can fly on spacecraft and do it remotely what we are trying to do instead is return a sample to earth. And there is a Japanese mission called MUSES-C which plans to go to an asteroid and land on it and pick up a sample and bring it back to earth.

When will a physical sample of an asteroid happen?

Within the next seven or eight years. It's a technical challenge, believe me. But they can they are going to land on the asteroid. They can just sort of go into orbit and slow down and get onto the asteroid and then it doesn't take much energy to leave it because the gravitational fields are so low. So, they land, they hop around, they open a little door and grab some rock and then blast off. They would have a little mini-engine on there and would blast off and then I think it must blast off and go back to a capsule, to an orbiting or hovering satellite and then the satellite comes back to earth.

This would be an unmanned robotic program?

Yes.

When it comes to NEAR orbiting 433 Eros, there was a comment in a newspaper that at the end of this mission, you might try taking a solar panel and tipping it toward the asteroid to scrape the surface.

Well, the idea if we could do it and again, this is pure speculation. It's in our dreams. But after we've completed the mission and the end of the mission gets us down into a 30 kilometer orbit so we can get close to the surface. And again, for the purpose of getting signal from this gamma ray and x-ray spectrometer which will give us compositional information about the elemental make-up of the surface after we have completed that, if there is fuel left, we wanted to slow down the spacecraft so it would get close down to the surface and we have these 4 solar panels that form a cross at 90 degrees to each other and if one of the solar panels could scrape the surface, then we'd get to look, back off and image the surface, we would get to see what a fresh surface would look like, compared to a surface that's been exposed to space for millions or billions of years.

Would spectroscopy be able to do any kind of analysis on that freshly scraped area?

Yes. And we'd also hope to image that, to look at the brightness changes. And also, there is a NEAR Infrared Spectrometer that measures reflected sunlight and there has been a big debate in that field of studying reflected sunlight whether the surface is weathered whether there is space weathering due to exposure and exposure to solar radiation. It might darken the surface and changes our apparent reflected spectrum. So, that would be very interesting. That would be an active experiment we'd be interested in.

Is there a pragmatic reason in terms of earth development to study asteroids and their relationship to Mars?

Yes, and their relationship to us because when we study the asteroids, we are looking back in time and we're studying the pre-planet forming time of the solar system. What we learn about the planets goes into the building blocks of the earth and Mars, so it will tell us something about how earth got to be the way it is.

What about mining asteroids?

Yeah, mining asteroids is an interesting topic, too. In fact, I have a student who wants to pursue that. There have been many studies and people are working on it, but I always say we need an economic need for it. So, we have the materials that we need on earth. So mining the asteroids would be useful for building things in space, so it would have best applications for activities in space, but that's many generations off in the future.

We have to get a space station in orbit first.

Right, exactly. But it's fun to think about. There are no rubies or precious metals in the asteroids in sufficient quantities that we would have to spend the energy and money to go get them.

What elements are asteroids expected to have in greatest abundance?

Water and minerals. EROS is a dry asteroid, but then if you were looking at things that have value on earth, you'd want to go to an iron rich, iron asteroid because that has the iron minerals like platinum and palladium and other heavy metals that have value here on earth. But basically, we don't need them. We have enough of those here on earth.

So, if Eros is iron-rich, at some distant future it might provide valuable metals for earth.

We don't know yet if it's iron-rich. That's one of our speculations. We'll know that in a year. When we get the rest of our instrument analyses. For example, there is a magnetometer on the spacecraft. That's going to tell us if it's iron-rich or not. And if it has a magnetic field. And we also have to look at the density and density distribution to help us determine how much iron is there as well as from the gamma ray spectrometer. There is iron in it, but whether it's iron that's useful or a valuable metal is speculation.

When will you know what the magnetometer reading is?

Oh, that's a good question. They are getting magnetometer data soon, but I don't know the ate when that will be released. And also for the x-ray and gamma ray instruments, I can direct you to people working with those instruments and are the experts and so it might be fun to talk to them.

Are there any known asteroids that are known to have water in them?

Yes, there are some. There are many in the main belt. A large fraction of them do have water-bearing minerals. Whether it's water tied up as ice or whether it's water in clay like minerals is known in some cases, but not in others.

The thinking is that in space it might be possible to use some of the asteroids as sources of water if we had the technology to extract it?

Exactly. But it's a difficult process. It requires a lot of energy, and therefore, it's costly. But eventually, we'll be doing it.

Did the Clementine Mission around the moon ever confirm frozen water ice in craters?

Not confirm, but there was a report from the Clementine Mission that there was a high radar reflectance from inside a crater at the South Pole of the Moon. And that one possible interpretation of that high reflection was that the radar signal was penetrating beneath the surface and reflecting ice. However, another contradictory measurement from someone using radar on the ground looked at that same region and did not get the same high reflectance and was possibly saying their interpretation was off and the high reflection was due to some fortuitous geometry off of a rocky block. We're still looking for further evidence to refute or support the evidence of ice trapped at the poles of the moon.

We're looking forward to analyzing the NEAR Infrared Spectrometer which is looking at the reflected sunlight from the surface of EROS. And the reflected sunlight gives us a signature or fingerprint of different mineral compositions or abundances across the surface. We're looking at that to see if the suite of minerals on the surface is that of original material that condensed in the early solar system and hasn't been heated or changed much throughout the age of the solar system. Or whether the combination of minerals tells us that the surface has been heated and melted and evolved from some igneous or heating process.

The sun brightening and melting the surface?

Right. Either the sun brightening and melting the surface or that Eros was part of a larger body that generated enough internal heat to melt it from the interior. To have volcanic activity like we have on the planet on Mars and the earth and some of the asteroids in the solar system.

That might possibly explain why there is that very smooth saddle on Eros?

Yeah, it could possibly explain it. But the smooth saddle on Eros is just smooth in that region. Why aren't there any evidence of lava flows that we've seen yet? We have to remember that in the next year we are going to get better and closer and more detailed images of Eros so a lot more is going to be revealed to us. What we are looking at now is just the beginning.

But it's confusing, isn't it, that such a smooth area is juxtaposed against so many crater impacts?

Yes. This implies it's sort of a new region. In fact, you are elucidating the puzzle to me. You're making me realize it's much more intriguing. So, we don't know what's going on. I'm looking at new images every day to see if we are getting a closer view, to see what's fooling us. It could be that was the most recent event and there haven't been a lot of impacts since then. It could also be that we haven't looked close enough and when we get closer we'll see there are impacts imposed on that smooth area.

There will be new Eros images steadily over the next year?

Oh, absolutely. New images and data from the other instruments, too. On February 23rd, we start a maneuver which gradually changes the shape of the orbit and this process will occur over the next week at which point on March 3rd, they will exercise another spacecraft maneuver, they will fire the jets again, to make that orbit circular and that will be a circular orbit that is 200 kilometers from the surface of the asteroid. And they will stay there until April 1st.

Then they are going to transfer to a 100 kilometer orbit. They'll keep getting smaller (orbits) and getting closer and by the end of the mission, they will be in a 30 kilometer orbit (19 miles). The resolution of these images is going to increase by a factor of ten easily.

Which is only about 19 miles.

Yes. The resolution of these iamges is going to increase by a factor of 10 easily.

This is the very first time in mankind's history to have an up close and

peronal ability to do this kind of research on an asteroid, isn't it?

Right, this is the first time a spacecraft has orbited an asteroid and has used, will study the asteroid with a complement of six different instruments. Our previous studies of asteroids have merely imaged, taken pictures of, an asteroid as the spacecraft flew by. So, this is giving us an in-depth look not only of the whole asteroid but in different regions of the electromagnetic spectrum. It's going to give us the opportunity for coordinated studies and the info we extract will be much more detailed than it is from flyby images.

What happens to the Eros satellite at the end of its mission in February 2001?

(laughs) That's a good question. There's two things: any orbit around Eros is unstable, so there are two things that can happen when you have an unstable orbit it can either crash or it can be ejected from the gravitational field of the asteroid. So, one scenario is that if we put it in an orbit that will eject it from Eros and we have extra fuel and we go visit another asteroid. I don't know that we're going to have enough fuel to do that. And there are other costs to do that we have to maintain the ground operations facilities and activities. So that's not very likely. So, it will do one of two things. It will either crash or be ejected from the gravitational field of Eros.

Before it is allowed to crash, it might do that solar panel scraping of Eros?

Yes, that's one of the possible scenarios to touch down with the solar panel and scrape the surface, but that's just a possibility.

If it gets that close, you might not have control of it to prevent its crashing into Eros?

Well, if it gets that close, our instruments weren't designed to operate at that close range, so will we get useful data from our instruments that's a question I don't know the answer to.

You almost have to get to that point and see what's happening.

Well, we have to have enough time to look up from our data analyses and see again, we're trying to keep up with the data we're getting. We're also trying to plan the rest of the mission because we do have the opportunity in the later phases of the mission to go look at interesting places and we may want to go look at small features inside the saddle, for example, and get a closer look at the surface material in the saddle. So we may ask for an orbit that will take us perpendicular over the saddle at close range. We may want to fly through it.

Fly through the "heel of the shoe" part of Eros.

Exactly. And there are other surface features that we want to get a closer look at and that's what we are planning. It is in the plan to target our orbits to fly over interesting surface features and then use our compliment of six instruments to study it. Those are the things we are looking at now. Just crashing would be fun, but we've got to get our information first."

More Information:

February 25, 2000 front image of gouged saddle on Eros after a short engine burn on February 24, 2000 began tightening the NEAR satellite's orbit around the asteroid. Photograph courtesy JHUAPL.

NEAR's First Whole-Eros Mosaic (4 images) from orbit on February 14, 2000. Looking down
over the north pole of Eros at one of the largest craters on its surface which measures 4 miles (6 kilometers) across.
Inside the crater walls are variations in brightness that suggest layering of the rock in which the crater formed.
Photograph courtesy of JHUAPL.

Websites:

http://near.jhuapl.edu/

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