talline and amorphous ice differ at most by a few percent, the rate of temperature drop dT/dt, for a given t, should be 7 to 10 times faster for the amorphous ice.

For small R the time t' is too short and for large R the ratio T/T_0 is too close to unity to permit an observation from a fly-by spacecraft. Also, the planet's shadow visible from the earth is too narrow and too close to the bright disk of the planet (*14*) to permit terrestrial measurements. Eclipses of icy satellites (*15*) suggest an overall thermal conductivity lower than that of amorphous ice, indicating that, as for our moon, the intergranular contacts play an important role. Perhaps high-resolution observations of large features from future spacecraft may answer this question.

It is known (*16*) that in contrast to ring B, ring A shows brightness minima at orbital longitudes 70° and 250° and maxima at 160° and 340° (*17, 18*). The diffusion of water molecules from the outer toward the inner rings may contribute to this asymmetry because the differences in their Keplerian velocities would lead to the formation of amorphous ice preferentially on the leading outward and on the trailing inward quarters of particles which are big enough to be facing the planet in a synchronous motion (*19, 20*). Small particles undergo too many collisions to be synchronous (*21*), but they are covered with amorphous ice and would be similarly preferentially deposited, contributing to the brightness anisotropy and increasing the nonsphericity of the large particles (*22*). One expects the fresh ice to be brighter than the old ice, which may be covered with dust and sputtered (*7*). In this model, the absence of brightness asymmetry in ring B could be an indication of collisional destruction of synchronism because of a narrower range of particle sizes (*23*).

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3 February 1978; revised 26 June 1978

Age Determination of an Alaskan Mummy: Morphological and Biochemical Correlation

Abstract. *Aspartic acid racemization analysis of a tooth from an Alaskan mummy yielded an age at death of 53 (± 5) years, which correlates well with earlier estimates based on morphological features. This study illustrates the value of integrative approaches to paleopathologic problems and the importance of preserving rare specimens for the application of new techniques.*

A major factor in the success of the recent revival of paleopathology has been cooperation among scientists of many disciplines. The ongoing examination of an Eskimo who died 1600 years ago illustrates the value of this integrative approach in determining the cause and date of death and the age at death.

The body was discovered in a frozen state on St. Lawrence Island, Alaska, in 1972, and remained frozen until it was brought to Fairbanks in 1973. Zimmerman's postmortem examination revealed that the individual was a woman with a skull fracture and aspirated moss fibers in her lungs. These findings indicated that she had been buried alive, probably in a landslide, and suffocated (*1*).

The date of death was determined by two independent techniques. Radiocarbon dating of tissue from the cadaver yielded a date of A.D. 370 to 390 ± 90 (*2*). This date placed the life-span of the individual within the Old Bering Sea cultural phase (*3*) on St. Lawrence Island. The arms of the mummy were covered with tattoos, the details of which were subsequently brought out by infrared photography. The artistic motifs of the tattoos were similar to those seen in a variety of Old Bering Sea artifacts (*4*) and thus correlated well with the radiocarbon date in placing the mummy in this phase of Alaskan prehistory (*5*).

The woman's age at death was initially estimated on the basis of morphological features to be between 50 and 60. The breasts and ovaries were atrophic, there was marked dental attrition, and there was evidence of coronary artery disease, which is rare in premenopausal women. Two years later a second technique was applied to determine the age at death, a microscopic study of cortical bone from a rib specimen. Osteon density was that expected in modern normals in the age range between 50 and 59 (*6*). In 1977, 4 years after the initial examination of the body, a third technique, based on amino acid racemization, was applied to a preserved premolar.

Amino acid racemization dating originated as a method for estimating the age of fossil materials on a scale of 10^3 to 10^6 years (*7, 8*). The dating technique is based on the incorporation of L-amino acids exclusively into proteins by living organisms. Given sufficient periods of time over which proteins are preserved after synthesis, a number of spontaneous chemical reactions take place. Among these is racemization, which converts L-amino acids into their enantiomers, the D-amino acids. The different amino acids racemize at various rates, and these rates, as is the case with all chemical reactions, are proportional to temperature. Aspartic acid has one of the fastest racemization rates (k_{Asp}), and at 20°C the half-life of the reaction is 15,000 years (*9*). Thus, the older a fossilized material is, the higher its D-aspartic acid content or D/L Asp ratio. The age of such a specimen can be calculated from the D/L ratio, once the k_{Asp} for the fossil locality has been determined (*8*).

Recently, this method has been applied to tissues from living humans. At the mammalian body temperature of ~ 37°C, the racemization rate of aspartic

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acid is fast enough to generate measurable quantities of D-aspartic acid in metabolically stable proteins during the human life-span. D-Aspartyl residues accumulate in enamel (*10*) and dentin (*11*) proteins at a rate of 0.1 percent per year, whereas in the lens nucleus the rate is 0.14 percent per year (*12*).

On the basis of the extent of racemization in a tooth, an age can be calculated for a living individual. With dentin analyses, the racemization age can be expected to fall within ± 10 percent (± 2 standard deviations) of the individual's actual age (*11*).

An application of interest to physical anthropologists, paleopathologists, and those involved in forensic medicine would be the estimation of the age at death for human skeletal remains. If death occurred in the recent past or if the burial environment is relatively cool, the amount of postmortem racemization is negligible. The D/L Asp ratio in tooth protein therefore reflects the chronological age of the individual (*13*).

An opportunity for demonstrating this application is provided by the Eskimo cadaver. As a result of accidental inhumation 1600 years ago, this woman's body was well preserved in frozen soils. Racemization analysis of dentin [according to the procedures described in (*11*)] from a first upper premolar yields a D/L Asp ratio of 0.053. Using the equation (*11*)

$$\ln (1 + \text{D/L}) = 7.87 (\pm 0.39) \times 10^{-4}\ \text{yr}^{-1}\ t + 0.014$$

We calculated age (t) of 48 (± 5) years for the premolar. Five years is added to this age in order to correct for the age of the tooth. The age of the Eskimo woman at the time of death was thus 53 (± 5) years. The racemization age compares very closely with the two earlier estimates based on morphological features.

There are several implications of the reported and earlier (*10–12*) findings. The amino acid racemization technique may be of practical importance to gerontologists interested in purportedly longevous populations in Ecuador, Hunza, and Russia. Wildlife biologists could also use the technique to construct age profiles for natural populations of large mammals such as whales or dolphins (*14*) or nonhuman primates. Very slow rates of turnover in human proteins could potentially be measured (*10*). If racemization proves to be a widespread phenomenon in structural proteins, it may actually play some role in the aging process of long-lived mammals (*15*).

The application of the racemization method illustrates that, when available, multiple approaches are useful in solving paleopathologic problems. Specimens from such unique finds as mummies should be preserved, since techniques will undoubtedly be developed that will lead to the derivation of further information. Finally, studies of this and other Alaskan (*16*), Egyptian (*17*), and Peruvian (*18*) mummies amply demonstrate the value of a collaborative investigation by teams of anthropologists, pathologists, radiologists, biochemists, and other specialists.

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19. This work was supported by NSF grant EAR 77-14490 and NIH grant PHSAG0063801 to J. L. Bada.

14 February 1978; revised 25 April 1978

Deimos Encounter by Viking: Preliminary Imaging Results

Abstract. *Recent close flybys of Deimos by Viking revealed a smooth-appearing surface void of grooves. Higher-resolution pictures showed that the surface was actually covered with craters but that a regolith filled the smaller craters, giving the smooth appearance. The surface was also covered with boulders and bright streak-like markings analogous to base-surge or ejecta cloud deposits.*

During October 1977, the orbit of Viking Orbiter-2 (VO-2) was changed to yield five close flybys of Deimos, the outer moon of Mars, all within 1000 km. An orbital commensurability between VO-2 and Deimos of 5 to 4 was achieved when the orbital period of VO-2 was changed to 24.2 hours. Since the orbital period of Deimos is 30.3 hours, close encounters occurred every 5 days beginning on 5 October 1977. The closest flyby at 33 km (26 km from the surface) took place on 15 October 1977. The sequence of Deimos encounters was ended

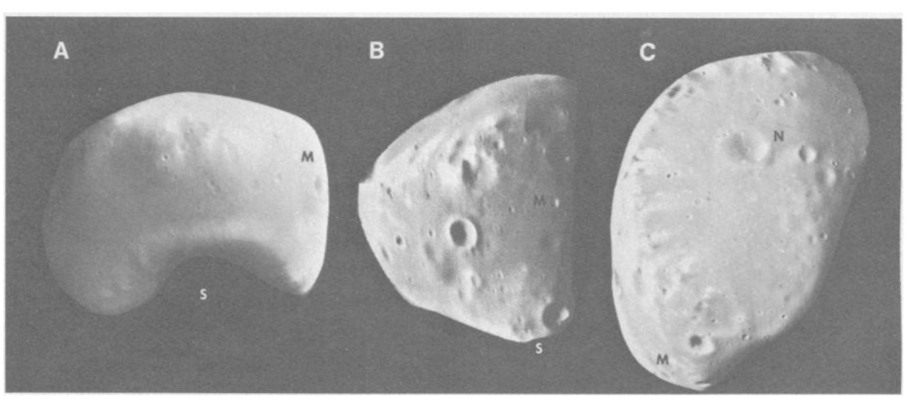

Fig. 1. Deimos viewed at three different perspectives at distances of (A) 1400 km, (B) 1900 km, and (C) 500 km. The illuminated areas are approximately 9 by 14 km with the sub-Mars point (*M*) and the north (*N*) and south (*S*) poles indicated. Even though there is a difference in resolution of a factor of 3 to 4 in these pictures, no significant increase in smaller freatures is revealed in (C). The apparent absence of craters smaller than 100 m in these pictures (pictures 413B09, 391B05, and 428B07) was found to be misleading.

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