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Terrestrial Ages of Meteorites

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ABSTRACT

The time since fall of a meteorite is an important parameter in the study of infall rates, meteorite distributions, weathering of meteorites and meteorite concentration mechanisms. Stony meteorites can weather quickly in humid environments, but the large numbers of meteorites found in semi-arid and arid environments suggest much longer survival times. Meteorites can survive in deserts for at least 50 kyr. Similarly, the cold and dry conditions of polar regions such as Antarctica have proved to be great stores of meteorites. Meteorites in Antarctica show an older terrestrial age distribution than for warmer locations. A few types of meteorites have been found in Antarctica with ages of up to 2 Ma. In this paper, I discuss the terrestrial residence times or terrestrial ages of these meteorites. I will also discuss the wide range of terrestrial ages from different environments, which show the effects of local effects on the storage of meteorites.

INTRODUCTION

Meteorites have been recovered since prehistoric times. The length of time these metal and stone “messengers from space” survive on the surface of the Earth has always been of considerable interest. Meteorites appear to fall equally all over the
world and have been recovered from all parts of the globe (Halliday et al., 1989, and chapter 16). In general, the infall rate can be described as a function of mass where:

\[
\log N = a \log M + b
\]

(1)

where \(N\) is the number of meteorites which fall per \(10^6\) km\(^2\) yr\(^{-1}\), of greater than mass \(M\) in grams. Halliday et al (1989) determined the constants \(a\) and \(b\) to be -0.49 and -2.41 for \(M < 1030\) g, and -0.82 and -3.41 for \(M > 1030\) g, based on observations of meteoroids. This would result in an infall rate of \(M > 10^9\) of 83 events per \(10^6\) km\(^2\) yr\(^{-1}\), or roughly one event per km\(^2\) in 10,000 yr. This topic is discussed in greater detail by Bland (chapter 15), who estimated an infall rate of 36–116 events per \(10^6\) km\(^2\) yr\(^{-1}\) based on meteorite weathering and recovery. A factor of 10 higher flux estimates were made by Zolensky et al. (1998), from the number of meteorites at Roosevelt County (New Mexico). This appeared to explain the concentrations of meteorites in Antarctica, as discussed by Huss (1990). This approach also ignored the question of transport of meteorites in Antarctic ice. Unfortunately, the age estimate for the Roosevelt County meteorites was not based on actual ages of the meteorites, but of cover sand deposits by thermoluminescence. Measurement of the terrestrial ages of these meteorites (Jull et al., 1991) showed a much wider range of ages. There is now general agreement with the infall rate of Halliday et al. (1989).

Despite the apparently uniform infall rate, meteorites are easier to locate in some places than in others. Large concentrations of meteorites can be recovered from areas of the Earth’s surface where weathering rates are lower, such as in deserts, or in polar regions, where concentration of the meteorites can occur due to ice flow, such as in Antarctica. Abundant recovery locations for meteorites include Antarctica (>17,000 individuals recovered), the Sahara Desert (>1500), the Nullarbor Plain of Australia (>280), Roosevelt County, New Mexico (94 samples), and many other desert environments such as Oman (Franchi et al., 1995), Saudi Arabia, and the Atacama and Namib deserts. Kring et al. (1998, 1999), for example, have recovered thousands of individual fragments of the Gold Basin meteorite, an L4 chondrite that fell in the desert of northwestern Arizona ~15 ka. Many organized searches of meteorites are continuing, especially in the deserts of North Africa, North America, southern Africa and the Middle East. A number of rare achondrites, such as Martian (or SNC) meteorites and one lunar meteorite have been recovered from these locations.

The length of time a meteorite has resided on the Earth’s surface obviously is a key part of its history and further, tells us much about how much we can learn from these objects and how much terrestrial alteration may have occurred. Since the composition of meteorites tells us much about the solar system and its history, terrestrial alteration of the meteorites is very important. Many studies rely on the pristine nature of a meteorite sample. Yet, studies of meteorite weathering effects in Antarctica (e.g., Gooding et al., 1988; Velbel et al., 1991) have not always generated much interest outside those specifically interested in these phenomena. For example, it was initially assumed that meteorites collected from Antarctica were pristine specimens, despite long storage in the polar regions. One important change in the importance of weathering phenomena was the discovery of carbonates of apparently Martian origin in the meteorite EETA 79001 and later some of its sister Martian meteorites. The discussion about the degree of terrestrial alteration of EETA79001 carbonates (e.g., Jull et al., 1997) has, however, largely been superceded by the much larger debate over Allan Hills 84001