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Half a century of progress in research on terrestrial impact structures: A review

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ABSTRACT

The author, who investigated the Wolfe Creek, Australia, in 1962 and edited two Benchmark Sets of Readings on Meteorite Craters and possible Astroblemes in 1977 and 1979, reviews the state of knowledge at the present time. The text is concerned with terrestrial impact structures, geological features, without any consideration of extraterrestrial analogues. A handful of definitive publications are drawn on to present the story of terrestrial impact in a single article. The text covers historical aspects (briefly); the effect of target variations; the paucity of human observation of such large-scale events; distinction from volcanic (endogenous) structures; modification by geological processes; the transience of the crater initially formed on the target, and its subsequent modifications; the global geographic distribution of the 174 structures now listed (of which a number are dubious attributions); their distribution in geological time (many ages being known only known to wide limits, maximum or minimum values); their size distribution; calculations of impact frequencies; shock effects; processes on impact; the stages of formation; impact into shallow marine and deep sea targets; impacts on ice (about which little is known); and finally the input of impact into biotic extinctions. In this last lengthy section, the summaries of the conclusions of scientists researching impact on Earth and palaeontologists researching biotic impact are set side by side. It is concluded that, if the recent foraminiferal evidence obtained by Gerta Keller and associates is taken at its face value, the case of impact as a sole agent in extinction is non-existent: biotic extinction is clearly a complex process involving a number of causes, in some cases it was staggered in time, and different sets of organisms responded quite differently and surprisingly, even in the same extinction event. Extraterrestrial impact may have been one of the causes in some cases, but it may have been regional rather than global in its effects. We may never know how much input it had into the record of biotic extinction on Earth? An enormous amount of new knowledge has arisen from detailed studies of this new family of remarkable geological structures.

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1. Introduction

Some 40 years or so ago the author published the first detailed description of the Wolfe Creek Crater in Western Australia (McCall, 1965). He later edited two sets of readings; on Meteorite Craters (McCall, 1977) and Astroblemes-Cryptovolcanic Structures (McCall, 1979). At that time there was an ongoing controversy as to the origin of the cryptic structures covered by the second volume, which had no association of meteoritical material, but were associated with shock metamorphic features. Indeed, even the Wolfe Creek Crater was controversial, for it was closely associated geographically with lamproite diatremes, albeit clearly geologically millions of years older than the crater, as evidenced by its degree of denudation by erosive agencies. Worldwide, there was a strong body of opinion favouring endogenous origin for such structures, led by Bucher (1963, 1965), Currie (1965, 1972) and Nicolaysen et al. (1963), Nicolaysen (1972). The present author was uncommitted in this argument, having come from a decade of study of volcanic rocks in the Rift Valley of Kenya, especially calderas (e.g. McCall, 1957; McCall and Bristow, 1965; McCall et al., 1970; Smith et al., 1995), and a decade of overseeing the meteorite collections in the Western Australian Museum while a Reader at the University of Western Australia.

In the years since that time, much discovery and research as left little or no doubt that the attribution of these cryptic to impact by extraterrestrial bodies will be overturned, as the author remarked in a historical review of the subject (McCall, 2006a). About 174 are now known on Earth and about 5 more are added to the list each year. It is also now certain that tektites, microtektites from marine sedimentary cores, microkrystites from the such cores and the Eltanin structure in the South Pacific Ocean, tektite-like bodies from near the K/T boundary in Haiti and Mexico, and tektite like bodies from late Devonian sediments in Belgium and China, are all related to such impacts, albeit to only a handful of such structures have such an association, though uncertainties remain about the exact physical process at the impact target which dispersed these glassy objects for thousands of kilometres (McCall, 2001a, 2006b).

It seems therefore appropriate to present, before the author's long sojourn on this planet comes to an end, a review of the hard facts now generally accepted worldwide, about terrestrial impact structures.

2. Historical

After Gilbert (1896) had concluded that it had originated in some endogenous cryptoexplosive geological process, Barringer (1906a,b) proposed an impact origin for Meteor Crater, Arizona, (now known as 'Barringer)', but this was not acknowledged by USGS until 1946. For the Ries Structure in Germany impact origin was proposed by Werner (1904), but until coesite was found there (Chao et al., 1960; Chao, 1967) there was a vigorous debate concerning its origin. Impact was unpopular and in Canada the Dominion Observatory, Ottawa, had to provide their own staff (e.g. Beals, Dence) to study the Canadian structures (see Dence, 1965 for their early results). On account of their persistence with investigations of possible impact structures in Canada, Grieve (2006) was able to list 29 such structures in Canada alone.

Dietz (1947, 1963) established shatter-cones as indicators (though there had been earlier suggestions of this) and planar features in quartz were recognised by McIntryre (1962) and Carter (1965). Later stishovite was added to coesite, both being quartz pseudomorphs indicative of extreme shock [coesite is now known from terrestrial highly tectonised rocks (e.g. Bolin Cong and Quinchen Wang, 1995].

There were initially strong opponents of impact theory, of whom Bucher (1963, 1965) challenged the attribution of Flynn Creek and