EVIDENCE FOR A LATE TRIASSIC MULTIPLE IMPACT EVENT ON EARTH

John G. Spray, Department of Geology, University of New Brunswick, Fredericton, CANADA Simon P. Kelley, Department of Earth Sciences, Open University, Milton Keynes, U.K. David B. Rowley, Department of Geophysical Sciences, University of Chicago, Illinois, U.S.A.

Recent redating of the Rochechouart impact structure of France [1] has drawn attention to the similarity in ages of at least four terrestrial impact structures: Manicouagan, Canada (214±1 Ma) [2], Obolon, Ukraine (215±25 Ma) [3], Rochechouart (214±8 Ma) [1], and Saint Martin, Canada (219±32 Ma) [4]. A fifth structure, Red Wing, U.S.A. (200±25 Ma) [5], is also close in age. If the continents are repositioned for Late Triassic times at 214 Ma, the three largest impact structures (from east to west), Rochechouart (25 km diameter); Manicouagan (100 km) and Saint Martin (40 km), are co-latitudinal at a mean paleolatitude of 22.8 , with a root mean squared deviation of 0.88, and a latitudinal width of about 1.2 . This is a remarkably good fit to a small circle path about the Earth's spin axis. The spread in paleolongitude is 42.8 .

The two smallest impact structures, Obolon (15 km) and Red Wing (9 km), have essentially identical trajectories with respect to the latitude-parallel trajectory of the other three. Obolon and Rochechouart (easternmost pair) define (by definition) a great circle that has a declination of 37.5 , while Red Wing and Saint Martin (westernmost pair) define (by definition) a great circle that has a declination of 42.8 . They thus have the same sense and essentially the same magnitude of rotation with respect to the small circle trajectory. If the longitudinal offset of 42.8 is removed for Red Wing and Saint Martin, while maintaining their latitudes, and a best fit great circle is computed for the four "end" craters (Red Wing, Saint Martin, Rochechouart and Obolon), the best fitting great circle has a pole at 37.21 N, 92.35 W, and hence a declination of 37.21 . Deviations of these data from the best fit great circle are remarkably small (<0.4).

From the age and spatial constraints, we conclude that Saint Martin, Manicouagan and Rochechouart were generated by projectiles that were probably co-axial with respect to each other (like Shoemaker-Levy 9 [6, 7]). The projectile that generated Obolon probably impacted at the same time as, and co-linearly with, the projectile that generated Rochechouart. Similarly, the projectile that generated Red Wing probably impacted at the same time as, and co-linearly with, the projectile that generated Saint Martin.

Lack of unequivocal projectile signatures in impact melt rocks associated with the five impact structures do not allow determination of projectile composition, and whether comet or asteroid. Rochechouart shows some evidence for a chondritic projectile [8]. Interestingly, the largest impact structure (Manicouagan) is at the centre of the five, while the smaller craters (Red Wing and Obolon) are peripheral - a feature noted for the Shoemaker-Levy 9 crater chain distribution on Jupiter [9, 10]. However, we consider it probable that there were more than five impact structures generated by the fragmented bolide. Those fragments that hit the Tethys ocean rather than Pangea, however, would have been subsequently destroyed by subduction.

The Late Triassic (and specifically the upper Norian) period coincides with one of the five main mass extinction events on Earth [11], an event possibly more catastrophic than that felt at the K/T boundary [12]. The Late Triassic also included the Carnian, smaller-magnitude mass extinction

event [13], which precedes the Norian. Four of the five impact structures have ages within the Norian Stage [14]. Red Wing lies within the Lower Jurassic (though its current age has large error, and it falls within the Norian, within error). Although Manicouagan has been suggested as a possible cause of Late Triassic mass extinction [2], the likelihood that it was accompanied by at least four other impacts at the same time adds new credibility to the association of mass extinction with bolide impact for the Late Triassic.

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