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EVENT-, BIO-, AND MAGNETOSTRATIGRAPHY OF THE KT BOUNDARY SECTIONS IN THE EAST BALKAN AREA, BULGARIA. A. Preisinger[1] and S. Aslanian[1,2], [1]Institute of Mineralogy, Crystallography and Structural Chemistry, Technological University, Vienna, Austria, [2]Permanent address Institute of Geology, Bulgarian Academy of Science, Sofia, Bulgaria.

KT boundary sections in the East Balkan area, south of the thrust and nappes of the Balkan Mountain, have been identified by biostratigraphic, mineralogical, geochemical, and magnetostratigraphic methods. From these investigations a real-time KT boundary was detected only on the coast at the Black Sea near the village Bjala, 35 km south of Varna [1]. The hemipelagic sediments of profile Bjala 2b and Bjala 2c show an Ir enrichment in the boundary clay, a minimum of $CaCO_3$ and $\delta^{13}C$, shocked quartzes, and a mass extinction of Cretaceous nannoplankton species, as well as a bloom of survivors at the KT boundary and the first appearance of new nannoplankton species after the KT event. Both profiles lie within the reversal paleomagnetic chron 29R. The comparison of biostratigraphic and magnetostratigraphic results provides a timescale for the evolution of these new nannoplankton species [2].

References: [1] Preisinger A. et al. (1993) *Palaeogeograph., Palaeoclimatol., Palaeoecol. 104.* [2] Preisinger A. et al. (1993)

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A GENERAL THEORY OF IMPACTS AND MASS EXTINCTIONS, AND THE CONSEQUENCES OF LARGE-BODY IMPACT ON THE EARTH. M. R. Rampino, Department of Earth System Science, New York University, New York NY 10003, USA.

The theory that large-body impacts are the primary cause of mass extinctions of life on the Earth now has a sound theoretical and observational foundation. A convergence of evidence suggests that the biosphere may be a sensitive detector of large impact events, which result in the recorded global mass extinction pulses. The astronomically observed flux of asteroids and comets in the neighborhood of the Earth, and the threshold impact size calculated to produce a global environmental catastrophe, can be used to predict a time history of large impact events and related mass extinctions of life that agrees well with the record of ~24 extinction events in the last 540 m.y. [1].

The search for impact signatures at extinction boundaries in the geologic record has produced six cases of diagnostic evidence of impacts (e.g., layers with high Ir, shocked minerals, microtektites), and at least six cases of elevated Ir of the amplitude expected from collision of relatively low Ir objects, such as comets. Recent detailed studies of the extinction boundaries show evidence of biological, isotopic, and geochemical signatures of sudden environmental crisis and abrupt mass mortality similar to those seen at the KT boundary [1]. A comparison of extinction rates and severity with the record of impact events provides a straightforward relationship—the greater the energy of the impact, the greater the mass extinction. The largest known craters have a significant correlation with the extinctions, including Manicouagan (~100 km wide), close to the end-Triassic; Doulon in China (~80 km) near the Jurassic/Cretaceous boundary; Popigai (~100 km) near the Eocene/Oligocene transition; and Chicxulub (≥200 km) at the KT boundary. A lower limit seems to exist, as impacts producing craters ≤50–60 km wide are not associated with global extinction pulses above background levels of extinction. A newly proposed impact structures on the Falkland Plateau (~350 km) may correlate with the end-Permian extinction (~250 m.y.), the most severe in the last 540 m.y. [2].

The formation and subsequent breakup of supercontinents and the coming and going of ice ages are among the major events in Earth history. Furthermore, within the plate tectonic paradigm they have been closely linked through changes in ocean-floor creation rates, sea level, volcanism, and atmospheric composition (CO_2 content) [3]. These would seem to depend strictly upon internal Earth processes (e.g., mantle convection, rising deep mantle plumes). However, recent evidence points to a possible role for asteroid and comet impacts in supercontinent breakup episodes, and in explaining several paradoxes pertaining to past ice ages.

Large impacts create magnitude ≥12 earthquakes, and such quakes could result in deep fracturing near impact sites, as well as in regions at great distances from the sites, where seismic waves are focused [4]. Impact-related fracturing could lead to cracking of the lithosphere, mantle melting, vast outpourings of lava (flood basalt eruptions), and development of hotspots. These might be most likely to occur in areas where broad upwellings or plumes in the mantle produced stresses that could be released by the impact-induced fracturing [3].

Correlation and possible cause-and-effect relationships among large-body impacts, extinction events, and continental flood basalt eruptions have been suggested [5,6]. Our previous work showed an apparent correlation between the ages of rapidly erupted continental flood basalts (CFBs) and extinction boundaries over the past 250 m.y. Use of new and more reliable $^{40}Ar/^{39}Ar$ and U-Pb age determinations on flood basalts improves the correlation.

This correlation is significant at the ~99% level [7]. We believe that these data support possible cause-and-effect relationships among impacts, extinctions, and flood basalt eruptions.

The breakup of supercontinents, such as Pangaea, are attributed to upwelling of hot plumes in the Earth's mantle, which eventually break through to the surface. The breakup events are often marked by flood basalts. The discrete ages of the flood basalt eruptions show that the breakup of Pangaea (and its southern region of Gondwanaland) occurred in a number of phases.

A clue to the possible association of supercontinent breakup and a large impact comes from events that took place at the end of the Permian Period (245–250 m.y.), a time marked by the most severe mass extinction of life in the geologic record (about 96% of species

TABLE 1.

CFBs	m.y.–*	m.y.†	Extinction Boundaries
Columbia River	16.2 ± 1	14 ± 3	Lower/mid Miocene
Ethiopian	36.9 ± 0.9	36	Eocene/Oligocene
North Atlantic	60.2 ± 2	61 ± 2.5	end Danian
Deccan	65.5 ± 2.5	65 ± 1	KT
Madagascar	86.5 ± 0.5 (new)	92 ± 1	Cenomanian/Turonian
Rajmahal	117 ± 1	110 ± 3	Aptian/Albian
Serra Geral	138 (new)	137 ± 7	Late Jurassic
Antarctic	176 ± 1 (new)	173 ± 3	Bajocian/Bathonian
Newark	201 ± 1	211 ± 8	end Triassic
Siberian	248 ± 2.5	255 ± 3	Permian/Triassic

* Errors are 1σ.

† $^{40}Ar/^{39}Ar$ age determinations or average of geological timescales were used for errors.

TABLE 2.

Continental Flood Basalts	Event
Columbia River (U.S.)	Failed break (?)
Ethiopian	Red Sea break
North Atlantic	Europe-Greenland break
Deccan (India)	India-Seychelles
Madagascar	Madagascar-Seychelles/India
Rajmahal (India)	India-Antarctica break
Serra Geral (South America)	South America-Africa break
Antarctic	Tranantarctic rifting
Karoo (South Africa)	South Africa-Antarctica break
Eastern U.S.	North America-Africa break
Siberian	Failed Siberian break (?)

became extinct). A large, roughly circular region of anomalous crustal deformation occurred around the present Falkland Plateau at the same time (248 m.y.). Geophysical and geological information allow the identification of one and possibly two circular basins (about 350 and 200 km in diameter) of possible Late Permian age on the Falkland Plateau—suggesting impacts of planetesimals 10–20 km in diameter [2]. The great impact may have provided a locus for the subsequent breakup of Gondwanaland, providing radial and concentric lines of weakness in the lithosphere, and possibly localizing the development of mantle convection patterns. This model may explain the similarity in timing of impactor showers, flood basalt eruptions, extinctions, hotspot outbreaks, and reorganizations of plate motion [3].

Major episodes of glaciation are recorded by diamictites interpreted as tillites in the Early Proterozoic (about 2.3 b.y.), Late Proterozoic (~850–600 m.y.), Late Ordovician (~435 m.y.), Late Devonian (~370 m.y.), and Late Paleozoic (~320 to ~250 m.y.). This leads to several climatic paradoxes: Late Proterozoic glacial deposits are found at all paleolatitudes, the early glaciations occur at times when atmospheric pCO_2 is predicted to have been high, and some glacial deposits are associated with warm climate indicators [8,9].

Numerous published studies have revealed that many recognized tillite sequences were actually the products of massive debris flows and large-scale "rainout" of coarse sediment. As a result, the tillites are now generally reinterpreted as glaciomarine debris-flow deposits, but this interpretation does not readily explain the scale and textures of the diamictites [8,9]. Recently, three groups have presented evidence that some inferred glacial sequences have many of the essential characteristics of ballistic debris-flow ejecta created by large impacts [8–10] and may contain evidence of shock [9]. Might some deposits interpreted as glacial in origin be ejecta of large impact events? If so, significant revisions in the long-term climate history of the Earth will be required.

References: [1] Rampino M. R. and Haggerty B. M. (1994) in *Hazards Due to Comets and Asteroids*, Univ. of Arizona, in press. [2] Rampino M. R. (1992) *Eos, 73*, 336. [3] Rampino M. R. and Caldeira K. (1993) *EPSL, 114*, 215–227. [4] Rampino M. R. and Caldeira K. (1992) *GRL, 19*, 2011–2014. [5] Rampino M. R. and Stothers R. B. (1988) *Science, 241*, 663–668. [6] Stothers R. B. and Rampino M. R. (1990) *GSA Spec. Paper 247*, 9–18. [7] Stothers R. B. (1993) *GRL, 20*, 1399–1402. [8] Oberbeck V. R. et al. (1993) *J. Geol., 101*, 1–19. [9] Rampino M. R., (1994) *J. Geol.*, in press. [10] Sears J. W. and Alt D. (1992) *Intern. Basement Tect. Assoc. Pub., 5*, 385–392.

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HYDROTHERMAL WITWATERSRAND GOLD MINERALIZATION CAUSED BY THE VREDEFORT MEGA-IMPACT EVENT? W. U. Reimold, Economic Geology Research Unit, University of the Witwatersrand, Private Bag 3, Johannesburg 2050, RSA.

Masaitis [1] recently reviewed many geological and morphological aspects that might render impact structures interesting and sometimes important economic geological targets. However, the role of hydrothermal processes that might be triggered by impact events and that, in connection with the effects of structural geological modification in and around an impact crater, might lead to mineralization of economic magnitudes has not yet been explored. Considering the enormous energies released on impact of even small projectiles [e.g., 2,3], this aspect should clearly be emphasized.

Dressler and Reimold [4] drew attention to the particular setting of the Vredefort Dome near the geographic center of the preserved Witwatersrand Basin (South Africa) with its exceptional Au and U deposits. An impact origin for the Vredefort structure was first suggested by Daly [5], and since the recognition of, particularly, shatter cones [6] and coesite and stishovite [7] this view has been accepted by the majority of geologists. However, this hypothesis has not remained unchallenged, and the discovery of structural complexities and of temporal relationships between the various deformation phenomena and geological events in the area of the Vredefort Dome led to critique of the impact model for this structure [8,9]. Modeling the size of the 2-Ga [10] Vredefort structure on the basis of radial distribution of shock effects, such as shatter cones or planar microdeformations in quartz [11], resulted in diameter estimates ranging from 180 to 300 km, with preference given to the upper limit. This places the Vredefort structure in the same size range as the buried Chicxulub Crater structure, for which a 300-km diameter has just been determined [12]. Clearly the lack of any other impact structure of such size (the next largest would be the deeply eroded (similar to Vredefort) Sudbury structure that probably originally measured <200 km in diameter [13]) implies that continued detailed study of the exposed remnants of the Vredefort structure is of utmost importance for the understanding of large impact cratering events and the resulting formations.

Various groups have studied the role of hydrothermal alteration in impact structures [e.g., 14–17]. It was suggested that within the confines of an impact structure extensive circulation of impact-heated fluids could take place [18]. Such effects are not only known from large impact structures [e.g., 15], but were noted in very small structures as well [e.g., 16]. Like the origin of the Vredefort structure by either endogenic or exogenic processes, the formation of the Witwatersrand ores has been controversial. An avidly conducted argument between those workers favoring a detrital origin of the Witwatersrand gold and a second school of "hydrothermalists" has been carried out [19]. To date many geologists studying the Witwatersrand Basin support the so-called "Modified Placer Hypothesis" for the formation of these ores, by partial remobilization of primary detrital deposits. However, source and nature of the fluids that caused large-scale remobilization of gold and other base metals throughout the ~40,000 km^2 of the Witwatersrand Basin have not yet been identified or resolved. Some workers believe that these fluids were liberated during the extrusion of the 2.7-Ga Ventersdorp lavas, while others have related a basin-wide 250°–400°C metamorphic phase of post-Ventersdorp age with base metal