

thermal metamorphic features with the thermal model may improve our knowledge of the geologic process connected with impact cratering.

References: [1] Melosh H. J. (1990) *Impact Cratering: A Geological Process*, 245 pp. [2] Pevzner L. A. et al. (1992) *LPSC XXIII*. [3] Ivanov B. A. (1988) *LPSC XIX*, 531-532.

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THERMOBAROMETRIC STUDIES ON THE LEVACK GNEISSES—FOOTWALL ROCKS TO THE SUDBURY IGNEOUS COMPLEX. R. S. James¹, W. Peredery², and J. M. Sweeny³, ¹Geology Department, Laurentian University, Sudbury, Ontario P3E 2C6, Canada, ²INCO E.T.S., Copper Cliff, Ontario P0M 1N0, Canada, and ³Falconbridge Limited (Exploration), Falconbridge, Ontario P0M 1S0, Canada.

Granulite and amphibolite facies gneisses and migmatites of the Levack Gneiss Complex occupy a zone up to 8 km wide around the northern part of the Sudbury Igneous Complex (SIC). Orthopyroxene- and garnet-bearing tonalitic and semipelitic assemblages of granulite facies grade occur within 3 km of the SIC together with lenses of mafic and pyroxenitic rock compositions normally represented by an amphibole ± cpx-rich assemblage; amphibolite facies assemblages dominate elsewhere in this terrain. These 2.711-Ga gneisses were intruded by (1) the Cartier Granite Batholith during late Archean to early Proterozoic time and (2) the SIC, at 1.85 Ga, which produced a contact aureole 1-1.5 km wide in which pyroxene hornfels are common within 200-300 m of the contact.

A suite of 12 samples including both the opx-gt and amphibole-rich rock compositions have been studied; typical mineral compositions are $OpxXmg = 0.55-0.60$, $GtXpyr = 0.12-0.32$, $PlgAn = 0.25-0.40$ in the felsic and pelitic rocks; in the mafic gneisses Cpx has $Xdi = 0.65-0.77$ and $Al-Tsch = 0.036-0.043$ and amphibole compositions are Edenite with $(Na+k) = 0.52-0.77$ and $Si(iv) = 6.4-6.9$. Garnets in the semipelitic gneisses are variably replaced by a plg-bio assemblage. Thermobarometric calculations using a variety of barometers and thermometers reported in the literature suggest that the granulite facies assemblages formed at depths in the 21-28-km range (6-8 kbar). Textures and mineral chemistry in the garnet-bearing semipelitic rocks indicate that this terrain underwent a second metamorphic event during uplift to depths in the 5-11-km range (2-3 kbar) and at temperatures as low as 500°-550°C. This latter event is distinct from thermal recrystallization caused by the emplacement of the SIC; it probably represents metamorphism attributable to intrusion of the Cartier Granite Batholith. These data allow two interpretations for the crustal uplift of the Levack Gneisses: (1) The gneisses were tectonically uplifted prior to the Sudbury Event (due to intrusion of the Cartier Batholith); or (2) the gneisses were raised to epizonal levels as a result of meteorite impact at 1.85 Ga.

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THE CRETACEOUS-TERTIARY (K/T) IMPACT: ONE OR MORE SOURCE CRATERS? Christian Koeberl, Institute of Geochemistry, University of Vienna, Dr.-Karl-Lueger-Ring 1, A-1010 Vienna, Austria.

The Cretaceous-Tertiary (K/T) boundary is marked by signs of a worldwide catastrophe, marking the demise of more than 50% of all living species. Ever since Alvarez et al. [1] found an enrichment

of Ir and other siderophile elements in rocks marking the K/T boundary and interpreted it as the mark of a giant asteroid (or comet) impact, scientists have tried to understand the complexities of the K/T boundary event. The impact theory received a critical boost by the discovery of shocked minerals that have so far been found only in association with impact craters [2]. One of the problems of the K/T impact theory was, and still is, the lack of an adequate large crater that is close to the maximum abundance of shocked grains in K/T boundary sections, which was found to occur in sections in Northern America. The recent discovery of impact glasses from a K/T section in Haiti [3,4] has been crucial in establishing a connection with documented impact processes. The location of the impact-glass findings and the continental nature of detritus found in all K/T sections supports at least one impact site on or near the North American continent.

The Manson Impact Structure is the largest recognized in the United States, 35 km in diameter, and has a radiometric age indistinguishable from that of the Cretaceous-Tertiary (K/T) boundary [5]. Although the Manson structure may be too small, it may be considered at least one element of the events that led to the catastrophic loss of life and extinction of many species at that time. The Manson crater is completely covered by Quaternary glacial sedimentary deposits that are underlain by flat-lying carbonate sediments of Phanerozoic age as well as Proterozoic red clastic, metamorphic, volcanic, and plutonic rock sequences. In the 35-km-diameter zone that marks the extension of the crater the normal rock sequence is disturbed due to the impact, and at the center of the structure granitic basement rocks are present that have been uplifted from about 4 km depth. The Manson structure was established as an impact crater on the basis of its geomorphology (circular shape, central uplift), the presence of shock metamorphic features in minerals (e.g., multiple sets of planar lamellae in quartz), Bouguer gravity data, aeromagnetic and ground magnetic data, as well as seismic surveys [6].

Detailed studies of the geochemistry of Manson target rocks (approximated by the drill core samples of the Eischeid #1 well, near the crater) and impact melt rocks and breccia samples [7] have shown that it is possible to reproduce the chemistry of the melt rocks and breccias by mixing various basement rocks. The elemental abundances in the black glasses found at the Haiti K/T boundary section are not incompatible with the ranges observed for target rocks and some impact glasses found at the Manson crater [7]. Most elemental abundances measured in the black glasses are within the range for the Manson rocks, and elemental ratios such as Th/U and La/Th are also compatible. The Rb-Sr and Sm-Nd isotopic signatures of the black glass are compatible with a continental crustal source [3]. In principle, this would apply for Manson rocks, but no definite conclusion can be made as the isotopic characteristics of the Manson rocks are not yet known. The yellow glasses, on the other hand, may require a different source material, as no rocks with such high Sr or S content have been observed in sufficient quantities in the Manson target rock stratigraphy. However, the target rock stratigraphy at Eischeid indicates abundant carbonates. I suggest that a more definitive answer can be obtained in the near future, when the samples from the newly drilled cores at the Manson structure are analyzed in more detail. These cores are just now becoming available for studies.

A second candidate for the K/T boundary crater is the Chicxulub structure, which was first suggested to be an impact crater more than a decade ago. Only recently, geophysical studies and petrological

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