NEW DATA ON THE LATE PLIOCENE ELTANIN IMPACT INTO THE DEEP SOUTHERN OCEAN

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The late Pliocene impact of the Eltanin asteroid is the only known asteroid impact in a deep-ocean (~5 km) basin. This was first discovered in 1981 as an Ir anomaly in sediment cores collected by the USNS Eltanin in 1965[1]. The expeditions ANT-XII/4 (1995) and ANT-XVIII/5a (2001) of the *RV Polarstern* collected extensive bathymetric and seismic data sets as well as sediment cores from an area in the Bellingshausen Sea (eastern Pacific Southern Ocean) that allow the first comprehensive geoscientific documentation of an asteroid impact into a deep ocean (~ 5 km) basin, named the Eltanin impact[2-5]. Impact deposits have now been recovered from a total of more than 20 sediment cores (including up to 17 cores from the 2001 expedition) collected in an area covering about 80,000 km^2. Sediment texture analyses and studies of sediment composition including grain size and microfossil distribution reveal the pattern of impact-related sediment disturbance and the sedimentary processes immediately following the impact event. The pattern is complicated by the Freeden Seamounts (~57.5 S, 90.5 W; we previously called these the San Martin Seamounts, but they were officially named Freeden in 1999), a large topographic elevation that rises up to 2700 m above the surrounding abyssal plain in the area affected by the Eltanin impact. The impact ripped up sediments as old as Eocene and probably Paleocene that have been redeposited in a chaotic assemblage. This is followed by a sequence sedimented from a turbulent flow at the sea floor, overprinted by fall-out of airborne meteoritic ejecta that settled trough the water column. Grain size distribution of reworked sediments and ejecta reveals the timing and interaction of the different sedimentary processes.

One of the most remarkable characteristics of this impact deposit is the high concentrations of melted and unmelted meteoritic material [6] distributed across a large area of ocean floor. We estimate the total amount of meteoritic materials by measuring bulk Ir concentrations in the sediment (using 187 ng/g as the concentration of Ir in the meltrock and the precursor asteroid [7]), and by measuring the amount of meteoritic ejecta in the coarse fractions of the sediment. Such measurements of the original USNS Eltanin cores provided a 500 m estimate for the minimum asteroid diameter. Using data from the 1995 Polarstern expedition, Gersonde et al. [2] found this was too conservative and recommended a minimum diameter of 1 km. With the much greater areal coverage and large number of sediment cores from the recent expedition, we will be able to greatly refine the model for ejecta distribution. To date we have measured Ir concentrations in sediments from 11 of the new cores. Our initial interpretation of these data is that there is a region in the vicinity of the Freeden Seamounts comprising at least 20,000 km^2 in which the average amount of meteoritic material deposited was > 1 g/cm^2 (two sites have > 6 g/cm^2). This alone is enough material to support a 500 m asteroid. Beyond this is a region of about 60,000 km^2, mostly to the north and east, where the amount of ejecta probably averages about 0.2 g/cm^2. Another 400 km to the east, USNS Eltanin core E10-2 has about 0.05 g/cm^2, so we know that coarse ejecta probably occurs across more than 10^6 km^2 of ocean floor. A key to future exploration of this impact is to find evidence of the ejecta at sites more distant from the seamounts. We currently have almost no data from regions to the west or south of the Freeden Seamounts, but sediment cores documenting the impact time interval collected at distant locations are now being studied.

At least one site (PS58-281, just north of the seamounts) has more than 8 g/cm^2 of meteoritic ejecta. Near the top of 8.5 m of impact deposit in this core, this ejecta is interbedded with disturbed sediments in a graded unit more than 50 cm thick. One 2.5 cm interval has 150 ng/g Ir, or about 80% meteoritic ejecta, by weight. One 2.5 cm meteorite has been recovered and 10 g of meteoritic ejecta (0.5 to 8 mm) has been examined. Of this, 87% is asteroidal meltrock and 13% is meteorite fragments. Unmelted meteorites are most concentrated in the lower part of the ejecta-bearing sediments, consistent with their greater density, and thus more rapid settling time through the 5 km water column, relative to the vesicular meltrock. In this particular core, which is 8 cm in diameter, we estimate that we recovered in excess of 500 g of melted and unmelted asteroid material. This is clearly the most meteorite-rich region known on the surface of the Earth.

The impact was formerly dated to about 2.15 Ma [2]. This estimate was based on regional analyses of the geological record combining bathymetric and seismic surveys with detailed sedimentologic, geochemical (e.g., chromium and iridium anaomalies), biostratigraphic (diatoms and calcareous nanofossils) and principally on magnetostratigraphic studies of sedimentary deposits recovered in 3 piston cores. Only one of them apparently contained an adequately complete and continuous late Pliocene sequence, however, whereas a hiatus spanning major parts of the Matuyama Chron was encountered in the other two cores. The age assignment therefore essentially relied on the identification of the magnetostratigraphic Réunion Event (C2r.1n) and the *Thalassiosira kolbei - Fragilariopsis matuyamae* diatom zone directly above the impact related deposits in a single core. New chronostratigraphic data have been obtained on a series of 4 piston cores retrieved during cruise ANT-XVIII/5a in the wider vicinity of the Eltanin impact area. Initial correlation of their magnetic susceptibility records with previous data sets substantiated the age estimate of the impact event in the early Matuyama Chron. High-resolution integrated magnetobio-stratigraphic analyses provided convincing evidence, at least in two cores with high enough sedimentation rates in the critical interval, that the Eltanin impact not only predates the geomagnetic Réunion Event, but also the unnamed normal polarity event (C2r.2r-1) listed in the most recent Geomagnetic Polarity Time Scale. This finding would now constrain the Eltanin impact age to 2.511±0.07 Ma , between the top of the Gauss Chron (2.581 Ma) and the base of the C2r.2r-1 event (2.441 Ma), a climate period that has been affected by major glaciations on the Northern hemisphere.

Our most recent results suggest that the Eltanin asteroid was larger than the 1 km in diameter size originally proposed as a minimum based on the ANT-XII/4 results. This places the energy released by the impact at the threshold of those considered to cause environmental disturbance at a global scale and it makes the impact a possible transport mechanism explaining the presence of extinct Cenozoic microfossils in the transantarctic Sirius Unit. Although a crater structure representing Eltanin ground zero has not been discovered, the distribution pattern of sediment disturbance and ejecta deposits now allows us to better determine the central target area north of the Freeden Seamounts. The new age estimate of the impact places it at a time of rapidly fluctuating climate. One of our future goals is to corellate this impact to a high sedimentation rate site with an established oxygen-isotope stratigraphy. This would allow us to assess possible climatic effects of the impact event.

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