ESCUELA INTERNACIONAL DE ASTROBIOLOGÍA
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Origins of the Building Blocks for Life

Field guide to the Cretaceous strata of the Santander area, Spain

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Preamble
Most field guides are read after the field trip has occurred. Try to read this one before you go.

Introduction
Cretaceous strata of the Santander area were formed in warm shallow seas at the northern margin of Iberia, then a microcontinent situated between the opening Atlantic ocean to the west and the Tethys ocean to the east. Most of the sediments are bioclastic carbonates formed from the skeletons of marine organisms including calcareous algae, foraminiferans, corals, gastropods, bivalves, and echinoids. Corals, high-spired gastropods, and large, snail-shaped rudist bivalves (*Pseudotoucasia santanderensis*) are the most conspicuous fossils in the early Cretaceous limestones of the Magdalena Peninsula, whereas oysters, urchins, and inoceramid bivalve shell fragments are common in the late Cretaceous carbonates of coastal sections west of Cabo de Lata (cover image) and San Juan de la Canal.

Rifting associated with the initial stages of the formation of the Bay of Biscay produced a deep basin that is known as the Basque Cantabrian Basin (BCB). Shallow water carbonates in Cantabria are the time equivalents of deep-water deposits in the Basque region. This field guide focuses on the shallow-water (Cantabrian) sections of the BCB; deep-water sections at Sopelana, near Bilbao, and Zumaia, further east, are famous for exposures of the end-Cretaceous extinction horizon, the Paleocene-Eocene Thermal Maximum (PETM) interval, and many other geological and paleobiological phenomena.

Environmentally stressful geological events, such as the end-Cretaceous extinction and the PETM, tell us more about the operation of the Earth System than do the "background" conditions that normally prevail. From an astrobiological point of view, the end-Cretaceous extinctions demonstrate how vulnerable life is to cosmic forces and how long recovery takes to occur.

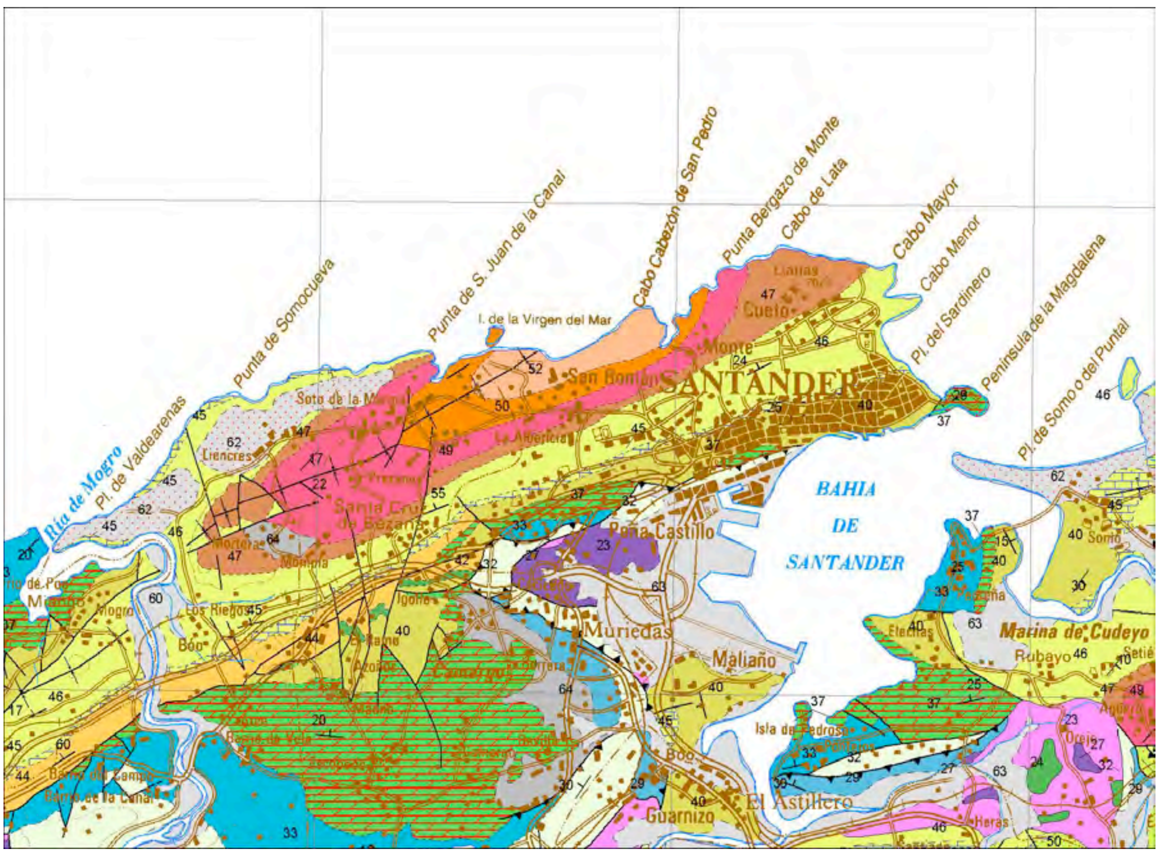
The end-Cretaceous event had a profound effect on Earth's biota. That effect was taken early on to mark the end of a major period of Earth history, the Mesozoic, and the start of the period we live in, the Cenozoic. It is now known with great certainty that the end-Cretaceous event was caused by the collision of a Santander-sized asteroid at a site (Chicxulub) that now lies beneath the Yucatán coast of Mexico. The environmental effects of this enormously energetic event caused the extinction of the dinosaurs, the demise of the ammonites, and the death of more than two thirds of the species living at the time. Famously, the first convincing signature for this asteroid collision was the discovery by a team of scientists at the University of California, Berkeley, of unusually high concentrations of the trace element iridium in end-Cretaceous boundary beds.

This excursion concentrates on biological events leading up to the end-Cretaceous extinction in a latest Cretaceous to earliest Paleogene (Tertiary) coastal section exposed at San Juan de la Canal, about 10 km due west of the Palacio de la Magdalena. No iridium-rich layer has yet been found in this section, but there is always hope!

Local geological context

The rocks of the Magdalena Peninsula are early Cretaceous in age (Aptian, ~115 Myr). They dip and young to the northwest. If one walks from the Peninsula along the beach (El Sardinero) towards the lighthouse on Cabo Major (cover image) one moves up section, but no rocks are exposed. From the other end of El Sardinero, there is a spectacular walk around the twin capes (Meno and Major) in strata of late Cretaceous age (Campanian, ~75 Myr). Finally, the east-west coastal section west of Cabo Major is of latest Cretaceous age (Maastrichtian, 71-66 Myr). At the end of the Cretaceous the carbonates change from gray limestones ($CaCO_3$) to brownish dolomites ($CaMg(CO_3)_2$), possibly in response to the global environmental change that followed the asteroid impact. However, as the stratigraphically lowest dolomites are unfossiliferous, it is hard to be sure exactly where the Cretaceous-Paleogene (K-Pg) boundary lies.

As one moves further west along the coast the dip of the strata diminishes and they become flat lying. This is the site of a syncline axis shown clearly on the accompanying geological map by the lines with opposing arrows. So, at Punta de San Juan de la Canal, the strata are dipping to the southeast and the whole K-Pg boundary section is repeated.



Part of the geological map of Cantabria showing the syncline of Cretaceous (greenish and brown) and early Paleogene (red and orange) strata in the Santander area. The Cretaceous-Paleogene (K-Pg) boundary lies at the transition from Cretaceous limestones of the Cabo Lata Formation (brown) to San Juan Formation dolomites (red). This trip is focused on the western limb of the syncline at Punta de San Juan de la Canal.

We'll begin the field trip by driving to the top of a ridge west of San Juan de la Canal. A short walk towards the coast gives one a view of a small island of late Cretaceous carbonates that is connected to the coast by a tómbolo (sand spit) at low tide. The strata forming the ridge are younger than those on the island. We will now walk along strike and then move up section towards San Juan. Here is a Google Earth image of the route. We're going to follow the path along the ridge from left to right. We'll go right to the end then follow the cliff edge down to the beach. The K-Pg boundary is just before the beach.

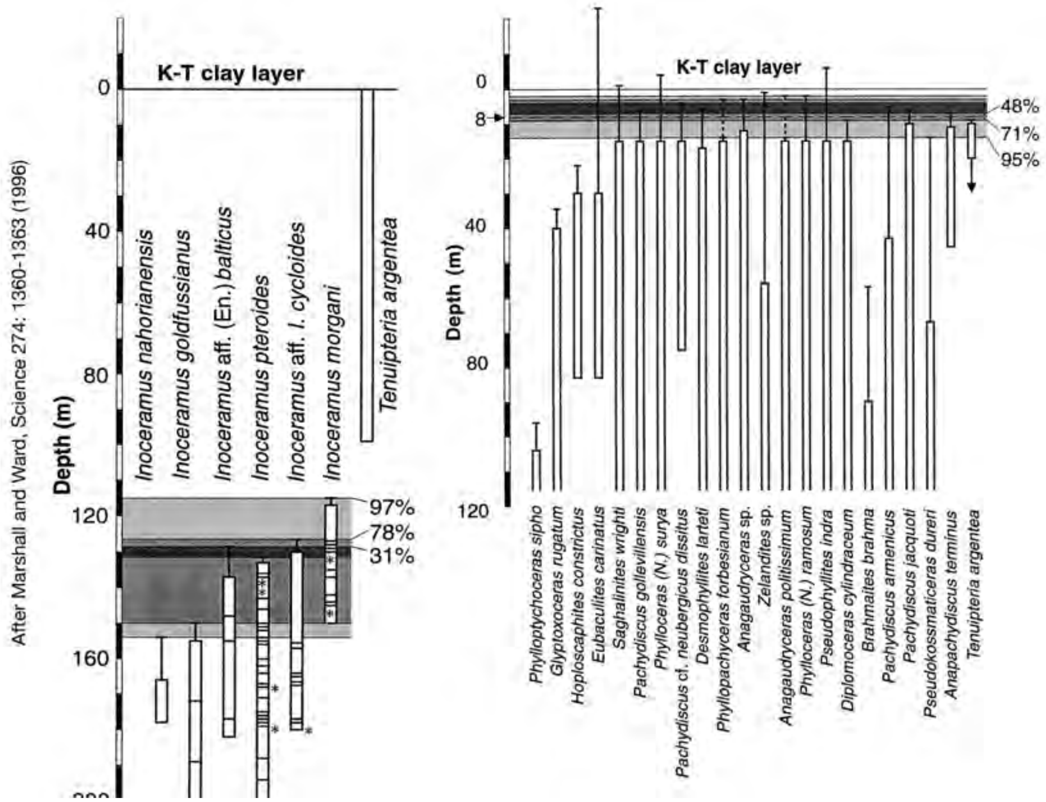
In order to interpret what we'll see, we need to know what happens in the deep water sections in the Basque part of the BCB at the end of the Cretaceous. On the next page there is a diagram from Marshall and Ward (1996). They used the observed abundances of fossils in the perfectly exposed section at Zumaia, east of Bilbao, to estimate when the individual species of inoceramid bivalves (left) and ammonites (right) went extinct.

According to this analysis, all six species of *Inoceramus* became extinct some time before the end of the Cretaceous. Only *Tenuipteria argentea* seems to have survived until the end. It was the last member of a major Mesozoic group of bivalves known as "inoceramids". These were generally large "flat clams", thin and fragile because their shells were made of calcite fibers. Fragments of inoceramid shells are therefore very distinctive and can be seen in abundance in this section.

The ammonites at Zumia tell another story. Although there are few fossils in the last few meters of the Cretaceous section at Zumaia, calculated range extensions (error bars) show that there is a high probability that most of the ammonites went extinct at the boundary. They were, indeed, victims of the catastrophe at the end of the Cretaceous.

We shall see the disappearance of the inoceramids and the subsequent persistence of the Cretaceous fauna (large echinoids) after the inoceramids disappear from the San Juan section. This tells us that we are getting pretty close to the K-Pg extinction horizon.

Does the progressive incoming of dolomite provide a clue? Is there more to learn from this section? Let's find out.



Observed occurrences of inoceramid bivalves (left) and ammonites (right) in the latest Cretaceous deep-water section at Zumaia in the Basque part of the BCB. The frequency of occurrences may be used to estimate the true durations of species. From Marshall and Ward (1996).

References

Marshall, C. R. and Ward, P.D. 1996. Sudden and gradual molluscan extinctions in the latest Cretaceous of the western European Tethys. *Science* 274, 1360-1363.

Masse, J-P., Arias, C., and Vials, L. 1998. Lower Cretaceous rudist faunas of southeast Spain: An overview. *Geobios* 22, 193-210.

Field Trip Stops

1. Distant view of the steeply dipping coastal outcrop of the Cenomanian-age Altamira Limestone near Liencres. The offshore island is Isla de Castro, formed of outer shelf carbonates of middle Late Cretaceous age. The island is connected to the Playa de Covachos—arguably the most beautiful beach in Cantabria— by a tómbolo that is only exposed at low tide.

2. Panoramic view of the city of Santander extending from the lighthouse at Cabo Mayor to the country to the west of Liencres. San Juan de la Canal and the Isle de la Virgen del Mar are in the middle distance. Flat-lying limestones and dolomites may be seen in the syncline axis beyond Virgen del Mar.

3. Base of the section that includes the Cretaceous-Paleogene boundary (stop 4). Here the finer-grained limestones contain numerous fragments of inoceramid bivalves and echinoid tests. Small faults cut across the sedimentary layers.

4. The Cretaceous-Paleogene boundary occurs in the deep notch next to the beach at San Juan de la Canal. Sedimentary layers on the beach side of the notch are composed of dolomite ($CaMg(CO_3)_2$), whereas those on the other side of the notch are mostly made of limestone ($CaCO_3$). Some echinoids but no inoceramid fragments can be found in the limestones (if the tide is low enough to allow exploration). This indicates that the limestones are latest Maastrichtian (latest latest Cretaceous) in age, younger than the time of extinction of most inoceramid bivalves (as seen at Zumaia).