Porcupine/Celtic Observatory –Atlantic Ocean

The Porcupine Seabight and Abyssal Plain area has been an important area for biogeochemical flux studies in the past but is also a very productive fisheries and oil-gas exploration area. It is a stable margin with little evidence of seismicity, but does have important deep water habitats.

Scientific context and relevance

The area of the Celtic Sea shelf into the Porcupine Seabight and out to the Porcupine Abyssal Plain (Fig 3) is the most intensively studied part of the European NE-Atlantic margin.

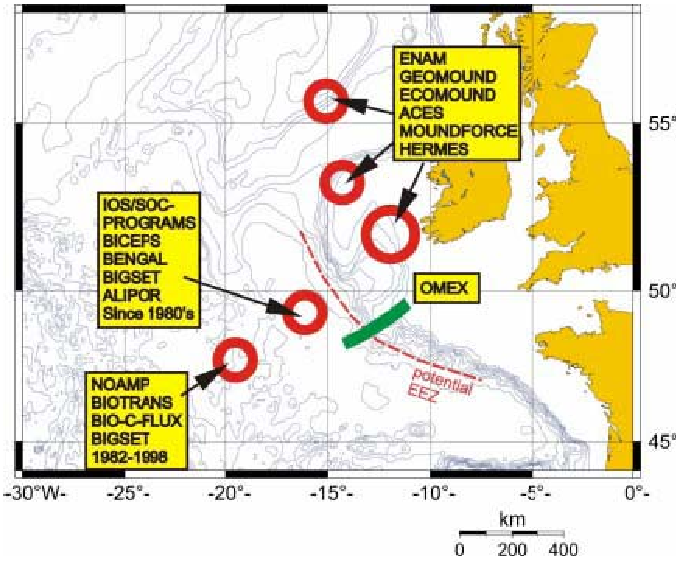

Figure 1 : ***The NW-European continental Margin in the vicinity of the Porcupine Seabight . In the last 25 years intensive time series studies have been carried out at Station PSB (UK & EU-programmes), PAP (UK & EU-programmes), BIOTRANS (German & international JGOFS programmes) and on the slopes and at Goban Spur, OMEX-Transect (EU-Projects).***

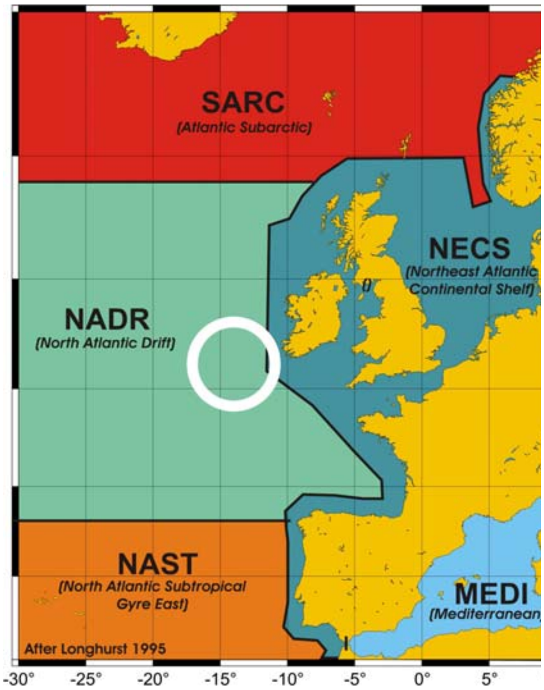

Figure 2 : ***The Porcupine/CeltNet area southwest of Ireland covers two biogeochemical provinces: NADR and NECS. Very high seasonal phytoplankton blooms occur in these provinces.***

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Scientific objectives

Recent scientific exploration .(FP 5 OMARC) along the European ocean margin proofed the existence of a deep-water coral ecosystem belt stretching from northern Norway to NW Africa extending into the Mediterranean Sea. The two colony forming stone coral species, *Lophelia pertusa* and *Madrepora oculata*, have the potential to construct impressive reef frameworks similar to their tropical cousins. They are essentially involved in the formation of the spectacular carbonate mounds off Ireland. Aside these structural aspects, deep-water coral ecosystems attract a yet unknown number of associated species that live permanently or temporarily there. Many of them are of economic importance. This important biological resource, however, is in many places severely exploited and under threat. Amongst a suite of human impacts to the deep coral ecosystems, demersal trawling creates by far the strongest destruction. We are just at the beginning to understand the functional role and the dynamics of the key species. Most intense occurrences are concentrated in areas where a complex seabed topography such as banks, ridges, seamounts, canyon systems exert a physical control on the deep current flow such as by the generation of topographically-guided filaments, current acceleration and density-driven convection. In this respect, the coral ecosystem acts as a benthic recorder of ocean circulation, nutrients and carbon flow. Therefore distribution of deep-water coral/ carbonate mound ecosystems at the Irish Atlantic frontier can be applied to understand the structure, functioning and dynamics under the particular trophic system of the NADR (North Atlantic Drift, Fig. 4).

The trophic state of the upper mixed ocean layer in the NADR is seasonally eutrophic with significantly pulsed particle exports from the upper mixed layer in spring and late summer. Of particular interest is the question: What is the influence of the NADR biogeochemical conditions on the biodiversity, functioning and dynamics of the coral/carbonate mound and other benthic ecosystems thriving under this trophic situation at present and in the past? Global change and the reaction of marine ecosystems can be addressed by investigating the change of biodiversity which occurred in deep-water coral ecosystems during the last glacial-interglacial cycle. While the now vigorously growing coral reefs in Scandinavian waters started to develop in a formerly glaciated environment just at the end of the Termination IB. the geologic history of the coral-capped carbonate mounds off Ireland probably extends back over the past 2 Million years.

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Coral-covered carbonate mounds of the Belgica Mound Province (BMP), north-eastern Porcupine Seabight are main targets for proposed long-term seafloor observatories. The BMP consists of about 25 exposed and 20 buried carbonate mounds that structure the continental margin in a confined depth limit between 600 and 900m (Figs 5, 6). Exposed mounds arise 50 to 200m above the adjacent seabed, thus forming topographic obstacles in the local current regime. While the shallower mounds are covered by early Holocene coral debris, flourishing coral ecosystems thrive along the summits and flanks of the deeper exposed mounds. Here dense thickets of colonial coral frameworks, produced by *Lophelia pertusa, Madrepora oculata,* and locally by stylasterids provide a complex 3-dimensional habitat for a species rich community of benthic and demersal organisms. was influenced by global change, i.e. the peaked Northern Hemisphere glacial-interglacial cycles.

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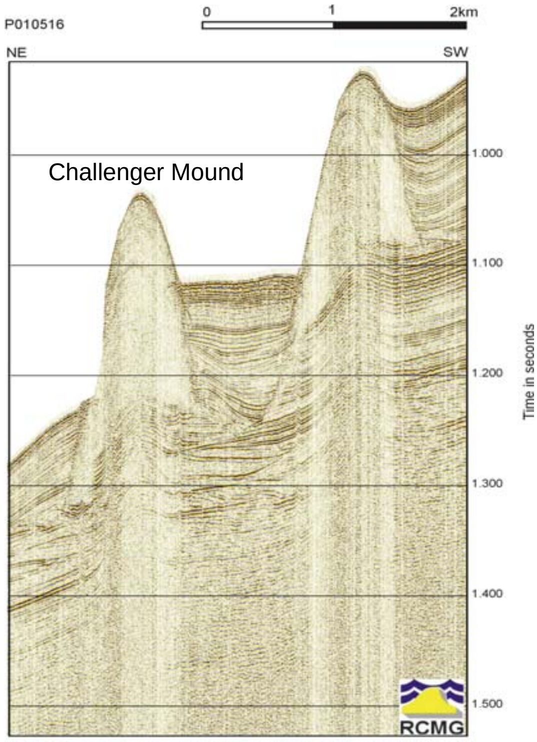

Figure 3 : ***Seismic profile across bathymetrically zonated mounds in the Belgica-Mound Province (data from Henriet, Gent University).***

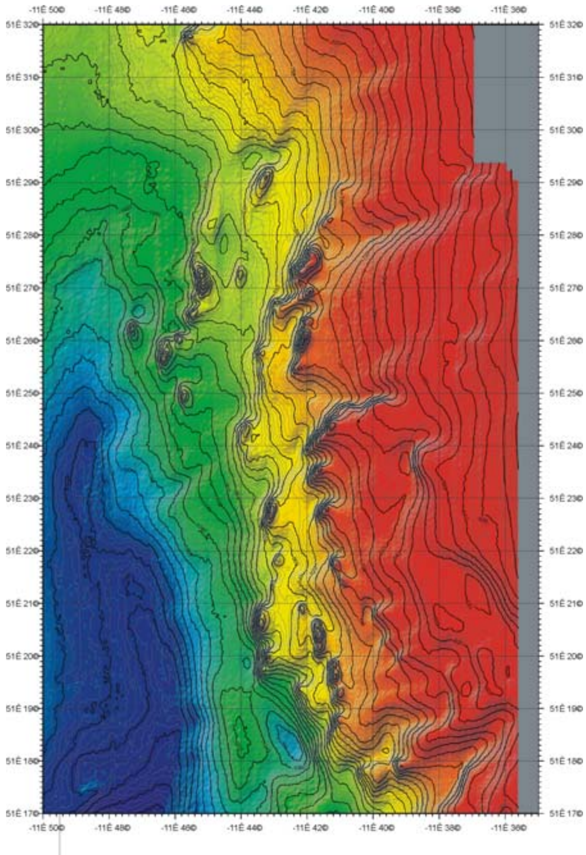

Figure 4 : ***The Belgica Mound Province on the slope of the eastern Porcupine Seabight between 600-1100m.***

Adjacent to the Irish continental margin extends the Porcupine Abyssal Plain (PAP). Surface water layer winter condition at PAP is of a mixed layer as deep as 500-800m driven by thermally convective overturning and wind forcing supplying nutrients into the upper mixed layer. With warming and reduced storm frequencies in spring the water column becomes more stable and a thermocline of about 50m thickness is established leading to major phytoplankton blooms (Figs 7, 8). PAP lies south of the main stream of the North Atlantic Current and is subject to return flows from this coming from the west and northwest. An intermittent stream of cyclonic and anticyclonic mesoscale eddies occurs across the area extending sometimes several thousand meters into the water column. During the past decade the intention has been to observe changes in rate and state variables within the entire water column and benthos for a wide range of biogeochemically significant features in the centre of the PAP (BENGAL Station). The site appears to satisfy many of the conditions for simplicity as it lies well apart from the continental margin where physical gradients are strong. It is situated in the middle of the biogeochemical province of the North Atlantic Drift and there is no evidence of significant advective supply of material. Processes at the seabed are dynamically coupled to upper mixed layer processes geared by atmospheric forcing The downward flux of particulate matter from the upper part of the water column has a profound effect on ocean biogeochemistry and hence on the global climate. As the material sinks it is subject to remineralisation and with increasing depth, the chemical components such as the green house gas $C0_2$ become more and more isolated from the atmosphere. Export below the winter mixed layer may isolate it from the upper ocean for decades or centuries. In deeper part of the water column (>1000m) long-term moored sediment traps have shown that there are strong regional variations in magnitude and seasonal variation in downward particle flux, controlled to a large extent by upper ocean biogeochemistry and plankton community structure (biological pump). Plankton dynamics produce strong seasonal signals as well as significant inter annual variations both in the timing and magnitude and composition of the organic matter flux to the sea bed.

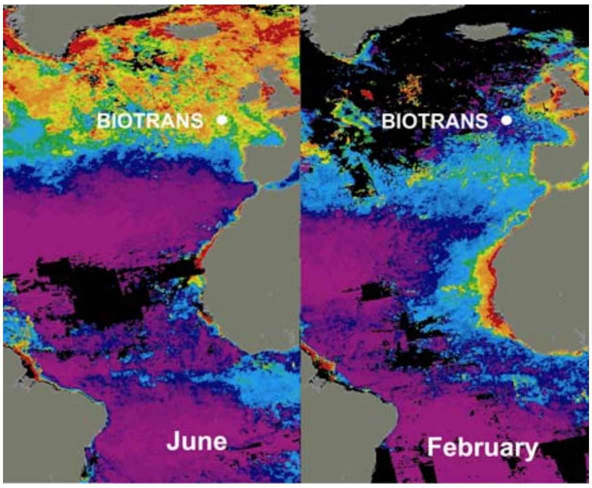

Figure 5 : ***Space view of the seasonal variation of phytoplankton chlorophyll biomass in the North Atlantic. The spring bloom is a process of large biogeochemical consequences for the marine ecosystems of the NW-European margin.***

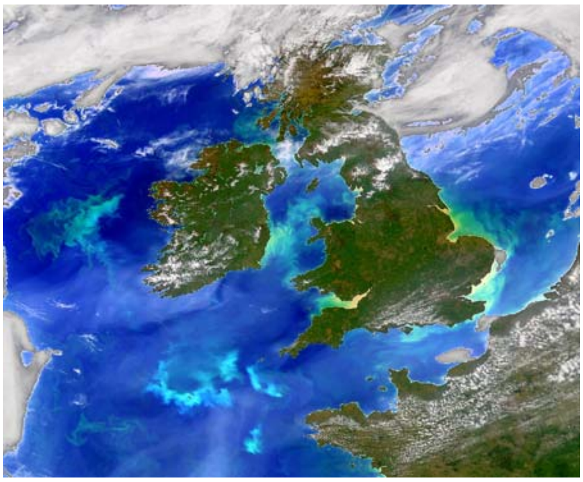

Figure 6 : ***Space view of intensive phyto-plankton (Coccolithoporids) blooms at the shelf edge of the NW-European margin in late summer. Blooms indicate the contours of Porcupine bank, PSB slope contour and Goban Spur.***

Life in the deep sea is almost entirely dependent on the fall out of organic matter from the surface layers. Therefore the abundance, biomass and composition of deep sea life are influenced by the patterns of surface productivity. The abundance of deep sea fishes is clearly influenced by surface production. Furthermore the flux from the surface varies both seasonally and from year to year in quantity and biochemical composition. In the NADR province on the Porcupine Abyssal Plain a strong seasonal deposition of phytoplankton has been repeatedly observed between late May and late summer at 4800m depth (Figs 9,10). Over time the composition of the deep sea fauna has changed possibly associated with change in fluxes to the deep sea influenced by the North Atlantic Oscillation. During 1997-2000 a sudden infestation of the Northeast Atlantic Ocean abyssal plain by sea cucumbers *Amperima rosea* (6457 ha^{-1}) and brittle stars *Ophiocten hastatum* (54,000 ha^{-1}) was detected If such events had occurred following some human intervention, such as deep sea waste disposal, it is likely that that the anthropogenic effect would have been held responsible. It is evident that the deep waters around Europe function as coupled systems and it cannot be assumed that the deep sea is uniform and stable but is in dynamic equilibrium with the upper ocean .Large scale changes occur that are very poorly understood. The central Porcupine Abyssal Plain location (PAP) in the NADR is the best monitored deep sea abyssal location in Europe. However monitoring only began in 1989 and a number of years are missing from the time series. There is an urgent need to establish continuous monitoring at this and other sites in order to track changes over time in the oceans around Europe. Simple exploration during single visits to locations is no longer adequate.

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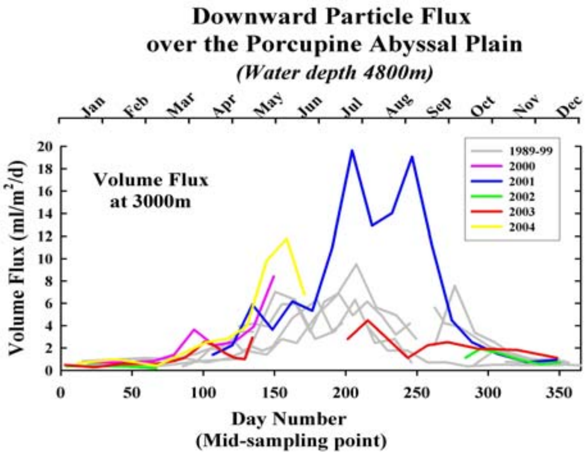

Figure 7 : ***Particle flux to the sea floor (19988-2004). Note the extreme inter annual and seasonal differences (data from R. Lampitt, NOC)***

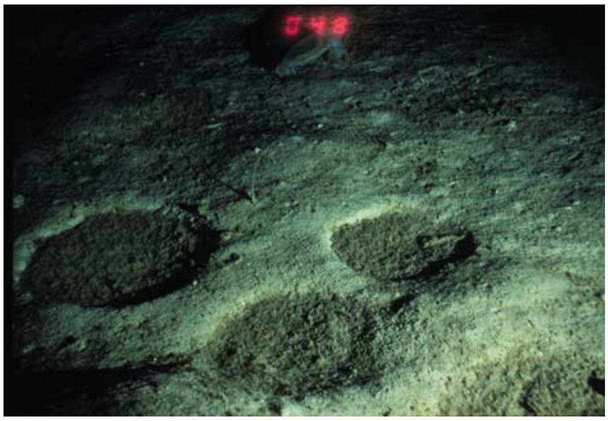

Figure 8 : ***Phytodetritus on the abyssal seafloor at PAP***

The continental margin and the Celtic Sea southwest of Ireland offers the unique opportunity to study processes in an extremely diverse habitat structure and biodiversity in combination with all major geo-morphological structures in a relatively confined area. These facts and the already existing data base led to the planning of a glass fibre optical based net work of observatories – **CeltNet** -in the Porcupine Region (Figs. 11, 12) within the FP-5 ESONET Project because:

- It encompasses all important deep-water habitats (except seeps) in a confined area.
- It contains large habitat diversity and biodiversity and thus an enormous genetic and natural product potential.
- It is located in a region, where global changes will manifest rapidly (changes in atmospheric forcing, currents, productivity, plankton and benthic biota, fish stocks).
- It contains ecosystems with high indicator potential, dynamically. responding to either natural or anthropogenic environmental changes (e.g. aphotic corals)
- It is impacted by economic interests (fishing, oil and gas prospection) and a high anthropogenic disturbance potential (shipping accidents).
- There is a strong demand for environmental protection (foundations of MPAs) by nature conservation stakeholder.

Some major objectives addressed by CeltNet are to make long-term systematic observations of marine abiotic and biotic processes and key parameters in the Porcupine region such as:
Climate change depicted by:

- coral biota response,
- other key biota response (e. g. sponge belt and abyssal megafauna)
- biodiversity and habitat changes
- productivity changes,
- biogeochemical changes (proxies),
- changes in the quantity and composition of deep water masses (salinity, temperature,
- current speed & direction),
- variation in surface water masses (integrity of the North Atlantic Current),
- changes in atmospheric forcing (e.g. NAO impact),

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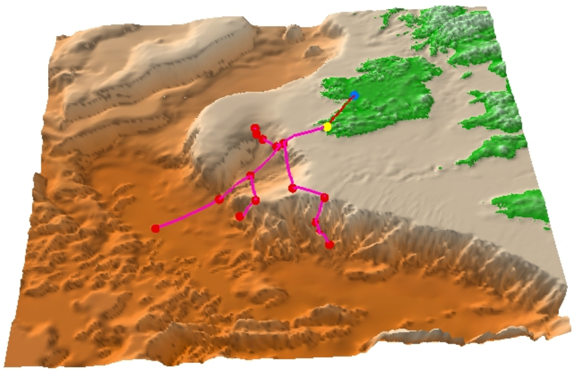

Figure 9 : ***The proposed CeltNet cable: A telescope into the NE-Atlantic.***

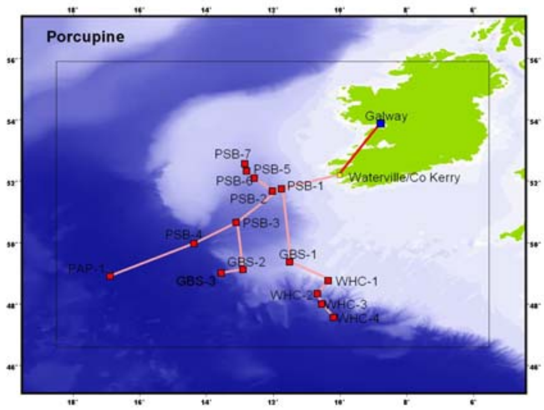

Figure 10 : ***The CeltNet cable system of approximately 1350km length covers all relevant continental margin features of the NW-European margin: shelf sea, slopes of different morphology (PSB, GBS), canyon (WHC), abyssal plain(PAP).***

Anthropogenic impact depicted by:

- coral and other biota response,
- biodiversity and habitat changes
- occurrence and distribution of pollutants

Transport processes at different margin morphologies:

- slope failures and sediment transport,
- canyons as conduits between the deep-sea and the upper slope,
- physical processes (e.g. tidal waves, internal waves, vertical mixing, upwelling, convection, filament formation).

Existing national and international programmes on the site

The extraordinary concentration of oceanographic research to the vicinity of the PSB and the repeated examination of the time series stations PSB, PAP and BIOTRANS led to a series of fundamental new insights and partly changes in paradigms on the functioning of deep water ecosystems: biodiversity, benthic-pelagic coupling, and long-term changes (global change) in deep-sea ecosystems. The spread of new surveying technologies in oceanography in the last decade (e.g. swath bathymetry, deep towed side scan sonars, ROVs, AUVs) resulted in the finding of geological structures and ecosystems of special interests such as carbonate mounds and deep-water coral reefs which have been lately intensively studied by programmes of the EU-OMARC cluster (ACES, GEOMOND, ECOMOUND). The Goban Spur continental margin transect investigations (OMEX) represents one of the few studies on the role and functioning of continental margins in the exchange of materials between continent and ocean as a basis for the development of predictive models of global environmental change.

The Celtic shelf and slope is a key area of industrial exploitation on the European continental margin with intensive fisheries down to about 2000m water depth and oil and gas prospecting. It is one of the main gate ways of global transport (shipping) with a high risk of environmental impacts by ship accidents with hazardous cargo. There is sound evidence of severe damage to ecosystems of special protectional need such as deep water coral reefs by trawling activity. The high biodiversity of the PSB and Porcupine Abyssal Plain (habitats, species) prompted international organisation (OSPAR) and natural conservation stakeholders (WWF) to demand the establishment of marine protected areas (MPAs) in the Porcupine Seabight/ Porcupine Abyssal Plain proper extending to BIOTRANS (Fig 3).

The western European continental margin southwest of Ireland is a focal locality of colliding interests between the conservation of an unique biodiversity (habitats, communities, species) and industrial exploitation (fisheries, oil, gas) with high risks of large area contaminations by hazardous ship cargos (e.g. oil spills in 2002 "Prestige", "Sea Empress"). To keep a balance between the health of the environment and human exploitation a sustainable management is needed. This can only be achieved with a monitoring strategy which includes the long-term observation of natural processes in combination with the monitoring of environmental impact parameters (physical, chemical, meteorological and climatological). A continuous observation should provide the data base for a series of forecasting models on the development of biological communities esp. fishable stocks, accidental pollution scenarios (alarms) and global climatological impacts.

Preliminary plan for the Porcupine Node:

A feasibility study for CeltNet is presently carried out within FP-6. The ESONIM Project identifies the best technical solution, provides the economic justification and suggests the appropriate legal structures to establish a seafloor observatory that conforms to the model defined by ESONET. ESONIM provides convincing reasons and the methodology required for national governments to implement seafloor observatories offshore Europe. ESONIM selected CeltNet as a model to demonstrate a transferable methodology to implement any of the ten proposed ESONET sites. A guide to scientific justification for a seafloor observatory site and a process for assessing revenue generation will be established, by inviting submissions from ESONET partners and interviewing end users of the proposed CELTNET site. The observatory architecture proposed by ESONET will be tested by an engineering design team who will select the best technical implementation solution for CeltNet. Using data provided by the engineering design team a business development team of financial and legal consultants will calculate the capital cost of installation, the running costs, the potential revenues, sources of funding and the cost of financing. Legal consultants will address insurance and indemnity issues, propose model contracts and suggest partnership agreements. Public private partnerships will be considered. The business development team will present a business model with a projected ten year cash flow forecast for the CELTNET site. The deliverables from ESONIM will be used by ESONET-NoE partners to petition their respective governments for support to establish seafloor observatories. ESONIM will promote and facilitate the take up of the results of ESONET and will contribute to the implementation of observing and forecasting systems to make long-term systematic observations of marine parameters necessary for global change research and management strategies.

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