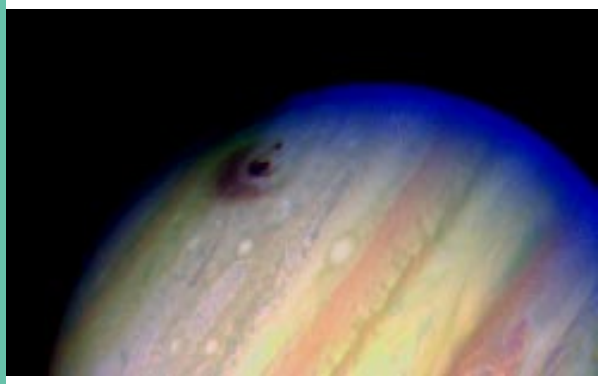
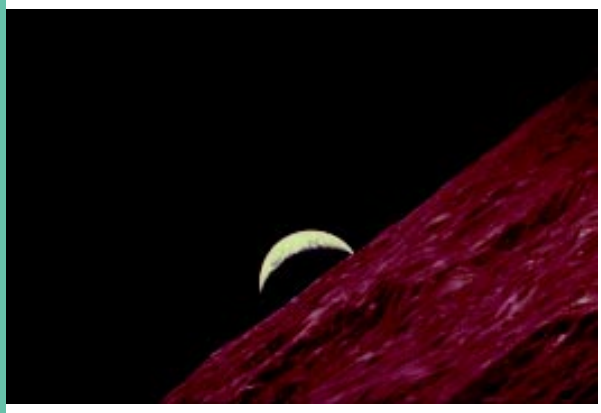


Impact of comet Shoemaker-Levy 9 on Jupiter in July 1994.

Response of the Earth System to Impact Processes (IMPACT)

An ESF scientific programme



Earth rise viewed from the densely cratered surface of the moon.

The European Science Foundation acts as a catalyst for the development of science by bringing together leading scientists and funding agencies to debate, plan and implement pan-European initiatives.

The ESF IMPACT programme aims at understanding the effects of asteroid and/or comet impacts on the development and evolution of the Earth. The programme is broadly interdisciplinary, gathering scientists from fields covering the whole realm of the Earth, Life, and Environmental Sciences. Impact is a key and common process in the solar system. In July 1994, the crash of comet Shoemaker-Levy 9 on planet Jupiter provided a "live" demonstration that the universe is indeed a violent place.

Astronomers and planetary scientists are familiar with such catastrophic events. They have documented the major role impacts play in shaping the surface of solid planets; the latest formation theory for the Moon indicates that it is the result of the collision of a Mars-size object with Early Earth. However, perhaps because of its catastrophic nature, geoscientists have in their majority been slower to accept that the impact of extraterrestrial objects influences the biological, and geological evolution of the Earth. In 1980, a team of scientists from the University of California at Berkeley hypothesised that the impact of a ± 10 km diameter asteroid or comet on Earth was responsible for the extinction of the dinosaurs and almost 50% of all species of fauna and flora at the end of the Cretaceous period, some 65 million years ago. Abundant evidence corroborating this hypothesis was gathered by US and European teams during the 1980s and culminated in 1990 with the discovery of the 200 km diameter Chicxulub impact structure buried under the tip of the Yucatan Peninsula in Mexico.

This impact/extinction hypothesis triggered major research on impact processes and the biological, climatic and geological response of planet Earth. The ESF IMPACT programme builds on this momentum to foster European contributions to this exciting and important research topic.

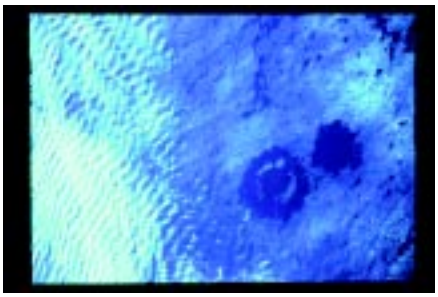
Scientific goals

The ESF programme is concerned with understanding the linkage between impact processes and the Earth System. It aims at documenting consequences of impact events on the Earth environment, including atmospheric, climatic, biological, and geological effects. A particularly important aspect of the programme's research focuses on the effects on the biodiversity of ecosystems. The ESF IMPACT programme covers three main areas of research.

1. The impact event

Knowledge of the physical and chemical constraints of the impact process itself is still limited. First, a better understanding of the astronomical background, especially concerning the population of Earth orbit crossing asteroids and comets, is needed. Telescope searches discover new Earth orbit crossing asteroids and comets on a regular basis. The record of craters on Earth must be better assessed; today only about 150 impact structures are known and only two marine craters have been found. Differences between impacts in a continental versus a marine environment need to be documented. Understanding the cratering process itself requires the detailed study of the impacted lithologies, coupled with highly sophisticated mathematical modelling. In this latter field – perhaps because it did not have an intense programme of military nuclear testing – Europe is behind the US and Russia. The ESF programme wants to develop such expertise in Europe.

The history of life and climate on Earth is recorded in sediment. Precise determination of the age of impact craters is important to establish potential links with the changes observed in the fossil record. As of today, many craters are still poorly dated. Thus, another priority of the programme is the systematic use of state-of-the-art methods to date impact craters and to correlate them with the sedimentary record.



2. Energy transfer to the environment

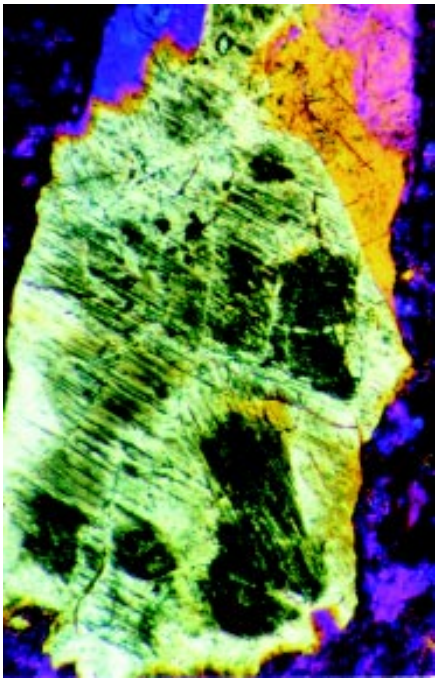
An asteroid or comet strikes Earth with a velocity ranging between about 11 and 72 km/sec. A large bolide will bury itself deep in the Earth crust, generating a huge crater. The mechanism of how the enormous energy released during an impact event is actually transferred to the atmo-, hydro-, bio-, and

Top: Impact lithology (breccia and melt-rock) from inside the Popigai crater in Siberia

Right: Satellite view of twin Clearwater craters (East and West) in Canada

geosphere is probably the least understood part in the chain that may link impact events with environmental changes.

An impact leads to the instantaneous generation of shock waves that penetrate the target area and attenuate in its environs. These shock waves affect the target lithologies by vaporising, melting, and shattering the target rock. The effect of this shock wave is visible in some minerals which show evidence of shock metamorphism.



Shocked quartz from the Manson crater in Iowa.

Recent studies, mainly triggered by the Cretaceous-Tertiary boundary impact/extinction scenario, seem to indicate that the injection of huge quantities of gases (CO_2, SO_2, H_2O) and dust in the atmosphere is the link between impact events and changes in the Earth System. Integration of the type of material and energy released by a large impact within present circulation and atmospheric models can illustrate how the perturbation is transmitted to, and influenced by the Earth System.

3. Effects on the environment

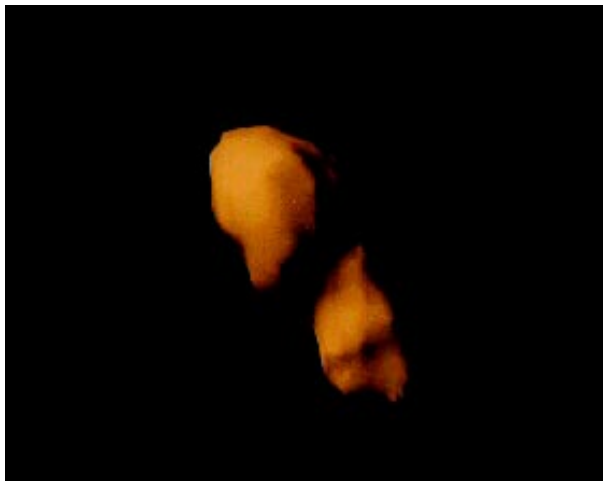
The response of the environment covers various topics, from the formation of economically important mineral deposits, as in the case of the Ni-rich Sudbury crater in Canada, to crater-fill sediments yielding exploitable hydrocarbon reserves, to major climatic and biological changes. Once the impact energy is imparted onto the Earth System, all the potential consequences and response of the environment need to be evaluated. Disruptions would include massive tsunamis, huge forest fires, as well as the introduction of large amounts of dust, water vapour, and various gaseous species into the atmosphere, and the deposition of hot and cold ejecta at great distance from the crater.

Ejecta layers are highly unusual formations and contain large quantities of rare siderophile elements, shocked minerals, nanometer-sized diamonds and glass. These markers are of prime importance to trace accretionary events in the sedimentary record, to identify their origin, and to evaluate their potential global effects. A major effort of the ESF programme is the meticulous search for impact layers in sediments throughout geological times.

Effects of impacts on the Earth's biodiversity need to be more precisely evaluated. Interpretations vary from complete scepticism to hypotheses that link all important evolutionary events to impact events. To reach a more balanced view, which is supported by sound facts, the obvious first step is to assess, as precisely as possible, which mass extinctions and/or global changes are clearly linked to impact events. Studies of taxonomic ranges or even relative abundance of species do not always produce significant patterns of biotic change, such as those observed at the Cretaceous-Tertiary boundary. The selectivity of

impact-induced extinctions and/or biotic changes is not known. What organism succumbs to which after-effect of impact events needs to be documented. This involves close cooperation between palaeontologists and experts on the physical and chemical markers of impacts, as well as high- precision dating. Such close interaction is being developed in the framework of the ESF IMPACT programme.

Finally, the hazards of impact events to humankind must be evaluated. This has been the topic of intense debates in the US and Russia, but received limited or no attention in Europe. The solar system contains a long-lived population of asteroids and comets that may strike the Earth. Around 90% of potential Earth impactors, collectively called NEOs (Near Earth Objects), are asteroids or short period comets. The other 10% are intermediate or long-period comets. The risk of an impact on Earth is small, but not zero. Once every 100 years or so, the Earth is struck by an NEO around 10 to 100 m in size that would be large enough to cause tens of thousands of deaths were it to strike an urban area. On a time scale of many thousand years, the Earth is impacted by objects in the range 100 m to 1 km, large enough to cause damage comparable to, or worse than, the greatest known natural disasters.



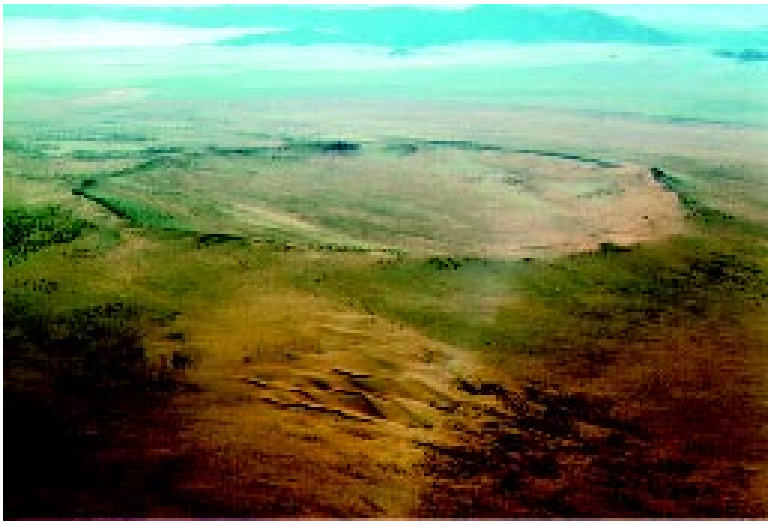
Computer-enhanced image of the 4.5 km Earth orbit crossing asteroid 4179 Toutatis.

Programme activities

Research and field workshops

Workshops are held twice a year in various European locations, either close to an impact site, a key stratigraphic sequence, a drill core storehouse, or at an experimental facility.

Roter Kamm crater in Namibia.



Students and young scientists are highly encouraged to present their results, and receive financial help to attend these workshops. Each workshop focuses on one key topic and tries to attract impact researchers and experts in closely related disciplines. A volume of peer-reviewed proceedings is issued for each workshop by a major Earth Science publisher.

Short course and educational activities

With a few exceptions, the curricula of Earth Science departments at European universities do not cover impact geology. The interdisciplinary nature of impact research makes it a difficult subject to teach within traditional discipline boundaries.

The ESF IMPACT programme has, thus, established a short course, designed especially for junior researchers, which takes place once a year and covers various aspects of impact research. The course aims at encouraging the teaching of impact processes in European universities by training the professors and researchers of tomorrow in this discipline.

Exchange grants

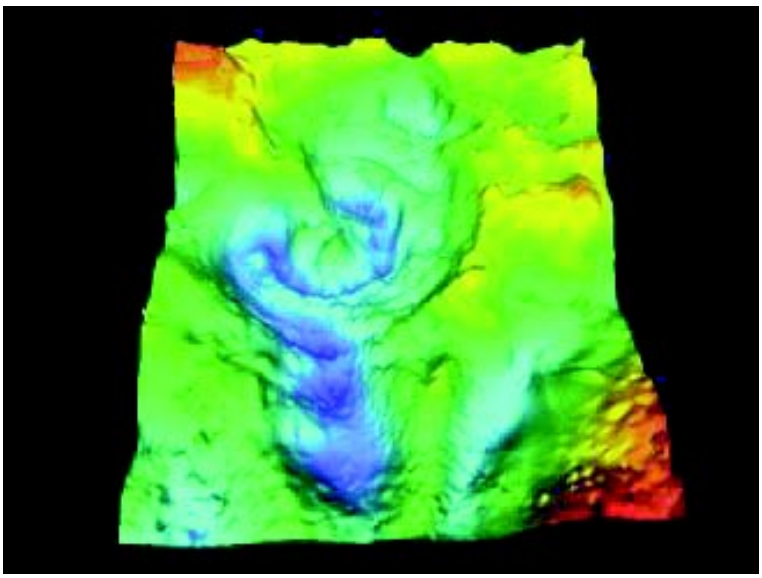
The ESF IMPACT programme offers a limited number of exchange grants to develop collaborative projects among European scientists. Grants are meant to provide a contribution towards travel and living expenses of young scientists, graduate students, or postdoctoral researchers when working in another European country.

A list of workshops and application forms for grants and the short course are available on the ESF IMPACT programme web site at http://psri.open.ac.uk/esf/

Newsletter and web site

With its newsletter, the ESF Steering Committee alerts the scientific community in Europe and elsewhere about the activities of the IMPACT programme. The Newsletter is published twice a year and distributed to more than 300 scientists.

Information and background can be found on the ESF IMPACT programme web page. An internet discussion list and news group has also been set up to facilitate contacts and exchange of information among impact researchers world-wide. The topics range from discussion of new results, to younger scientists seeking advice on techniques or methodology.



Model in 3 D of the Chicxulub crater in Mexico

Database of European impact researchers

A list of more than 300 researchers in Europe who have impact as a topic of interest has been established. The list is updated regularly and can be obtained by contacting the ESF IMPACT programme chair or secretary.

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For the latest information on this programme consult the IMPACT home pages (http://www.esf.org/lp/IMPACTa.htm) and (http://psri.open.ac.uk/esf/)

Pictures courtesy of Philippe Claeys, Christian Koeberl and NASA.

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