Environments and Ecosystem Dynamics of the Eurasian Neogene (EEDEN)

An ESF scientific programme

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.

Today mankind is concerned with drastic reductions in terrestrial biodiversity as habitats are reduced or altered by human activities. The geological history of terrestrial ecosystems is an important topic for both earth scientists and biologists, touching on such fundamental problems as environmental fragmentation versus biodiversity. Consequently, it appears timely to investigate past changes in terrestrial ecosystems and biodiversity dynamics, in particular those pertaining to the Neogene, a time interval that has witnessed enormous geographical and environmental changes in Eurasia. Yet the Neogene is close enough to the present that we can understand floral and faunal change by reference to present-day genera and species in present-day ecosystems.

It is self-evident that pan-European cooperation is essential inasmuch as the scale of the geological phenomena is large. It is only possible to investigate changes in whole ecosystems by bringing together specialists on all the important fossil groups, including vertebrates, molluscs and other terrestrial organisms, experts on the history of vegetation and on the external (including from marine sediments) evidence for changing climates, on the basic geological reconstructions such as those pertaining to land-sea distribution and palaeotopography, and on the construction and application of high-resolution time scales.

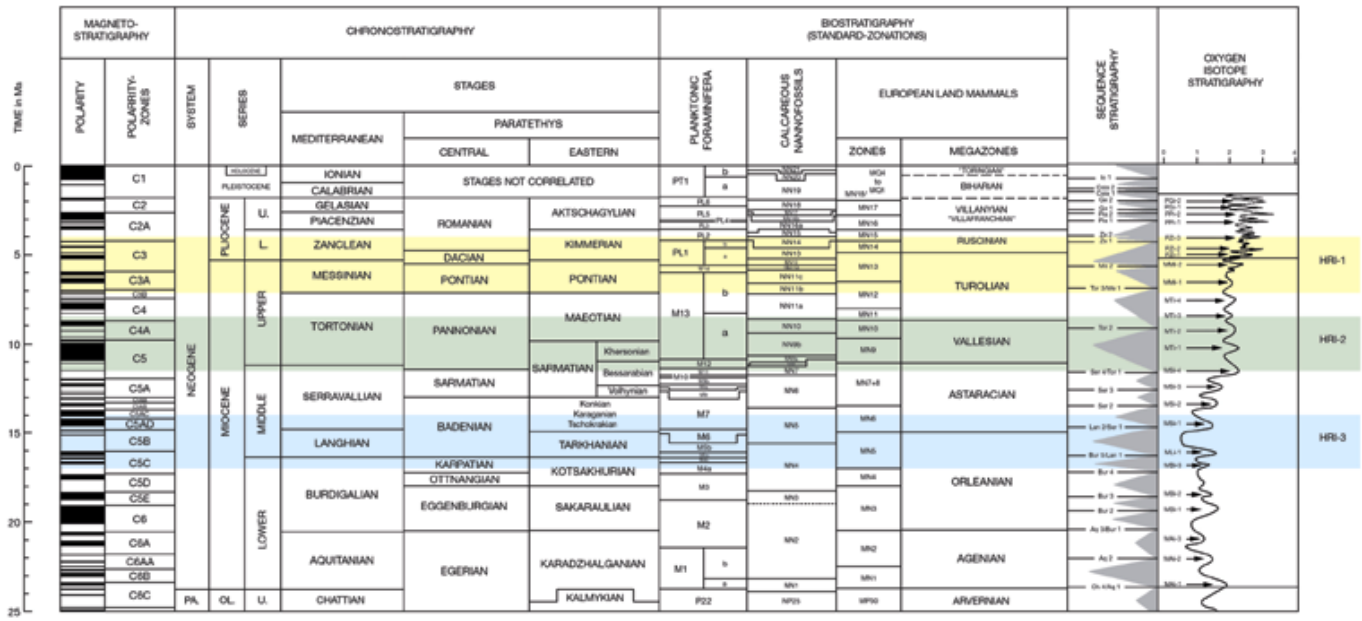
Modelling of terrestrial as well as marine palaeoenvironments and depositional systems is a prerequisite if we are to arrive at a "total system view" on the processes which controlled terrestrial ecosystem change, collapse and recovery during the Neogene. Neither recent advances in high-resolution chronology, nor the recent palaeogeographic and palinspastic reconstructions have yet been assimilated in this field. The same holds true for modern insights into the biological validation of palaeo-proxy records. By fulfilling these requirements, the EEDEN programme is considered a pioneering and most challenging attempt to examine terrestrial ecosystems in the framework of a new generation of temporal and spatial reconstructions.

Background

There is rapidly increasing interest in (semi-)quantitative studies of mammal associations straddling episodes of major ecosystem perturbations during the Neogene, in relation to the formation or break-up of migration corridors and/or the response to discrete events in regional and global climate history. Similar efforts are being made for other terrestrial groups of organisms. Invariably these studies aim at palaeoecology-oriented reconstructions of environmental change, based on the knowledge of life-habitats of extant relatives. Parallel to these developments, substantial progress has been achieved in the reconstruction and understanding of the evolution of Neogene regional and global climates, based either on the qualitative and quantitative elaboration of vegetation histories, or on the interpretation of marine biotic and abiotic records.

Notwithstanding these achievements it should be realised that first-order integrations between the various qualitative and quantitative interpretations pertinent to ecosystem change, which should constrain the nature and rates of climatic and other abiotic change thought to underlie the ecosystem perturbations are virtually lacking. Similarly, there have been hardly any indisputable high-resolution correlations between terrestrial and marine sequences, which would allow the inferences drawn from the terrestrial record to be compared unambiguously with those inferred from marine sedimentary sequences. In addition, changes in the nature and composition of terrestrial communities are as yet ill understood and as a rule not investigated in the context of sound palaeogeographical/palaeoenvironmental and palaeoclimatic reconstructions.

The dynamics of terrestrial ecosystems can, however, only be understood if high-resolution process-oriented studies are embedded in a much broader, multidisciplinary context. Consequently, there is an urgent need to enhance, for instance, our ability to discriminate between climate, sea level and tectonics-induced environmental changes, which, in turn, will aid to discriminate between local, regional and global causes of ecosystem perturbations. Within well-resolved time-stratigraphic, biogeographic and regional environmental frameworks it will then also become feasible to address in detail the kind of basic ecological questions that cannot be answered by studying the living world owing to the lack of temporal depth. It is timely and feasible now to combine the various fields of expertise pertinent to the development of Neogene ecosystems, palaeoenvironments and palaeogeography and then to integrate the parallel, geological and (palaeo)biological investigations into one conceptual research framework for the study of terrestrial community change, collapse and recovery.



State-of-the-art integrated stratigraphic correlation scheme for the Neogene. Coloured shadings indicate position of EEDEN High-Resolution Intervals 1 – 3

Programme outline and objectives

The encompassing aim of the EEDEN programme is the detailed analysis of the response of terrestrial ecosystems to environmental change through the integration of multidisciplinary studies focussing on some selected, already fairly well-known "high-resolution" time intervals in the Neogene of the Eurasian realm. These intervals are known to a) include major changes in the composition of terrestrial communities, b) portray large-scale palaeogeographical reorganisations and changes in overall environmental conditions in the terrestrial realm and c) allow the establishment of high-resolution stratigraphic correlations with data and interpretations pertaining to regional and global aspects of the coeval development of marine environments. They cover 1) the latest Miocene to Early Pliocene (HRI 1, 7 – 4 Ma ago), 2) the latest Middle Miocene to early Late Miocene (HRI 2, 12 – 8.5 Ma ago) and 3) the late Early to early Middle Miocene (HRI 3, 17 – 14Ma ago).

HRI 1. Studies on this interval will address terrestrial ecosystem perturbations in relation to the effects of regional and global environmental changes prior to, during and immediately after the "Messinian salinity crisis", which resulted from the severance of Atlantic – Mediterranean connections during the latest Miocene. HRI 1 also serves to investigate the direct and indirect effects of changes in oceanic circulation patterns, the growth of Antarctic ice sheets, the presumed amplification of the precession component in astronomical forcing, aridification effects and the expansion of C4 grasses, on regional climate and environment evolution and / or biotope development.

HRI 2. This interval portrays a sequence of mammal events where arrival of new groups that subsequently rose to dominance preceded major changes in mammal biotas. Similarly, important changes in the lower vertebrate record occur. Research efforts will focus on the detailed reconstruction of the temporal and regional aspects of migration events and community changes (e.g., "Vallesian crisis" in Western Europe) and their understanding in terms of the hypothesised interrelation between

Recent equivalents of two characteristic Neogene environmental settings.
Left: *Taxodium* swamp forest, Pearl River, USA, the modern analogue of north European Miocene and south European Pliocene coastal environments.
Right: Impoverished *Avicennia* mangrove, Red Sea, the modern analogue of south European Miocene coastal environments.
Insets refer to *Taxodium* and *Avicennia* pollen grains, respectively.

overall climate / environment change and reorganisations in Eurasian topography and land – sea distribution patterns.

HRI 3. Detailed analyses of this poorly understood interval are challenging and rewarding, as it comprises the first phase in the development of the later Neogene terrestrial ecosystems, expressed, for instance, in the mammal record by a major turnover and successive immigration events. The reconstruction and elaboration of these events will be studied in the context of the effects of global climate change and fundamental, large-scale plate-tectonic and palaeogeographical/palaeoenvironmental/palaeobiogeographical changes which affected the African – Eurasian convergent plate boundary during the late Early to early Middle Miocene.

Research strategy

Three lines of approach are envisaged:

The establishment of *terrestrial databases* will serve to make available the necessary data sets, enabling the detection of geographic and temporal trends in the terrestrial biota. These data sets will be maintained within several discrete but compatible databases, each with its own management system in place. These databases will partly elaborate on existing electronic data sets, such as NOW (Neogene of the Old World) and ETE (Evolution of Terrestrial Ecosystems) for mammals and on data bases being developed for the Neogene palynological and macrofloral records.

Research on *time-stratigraphic frameworks and palaeogeography* will focus on the detailed reconstruction and mapping of palaeogeographical and palaeoenvironmental settings for the three High Resolution Intervals on the basis of the combination and integration of terrestrial and marine evidence. The mapping will elaborate on the achievements of the Peri-Tethys programme and on the results of regional palaeogeographical / palaeoenvironmental reconstructions. The establishment / extension of astronomically-calibrated polarity time scales for both the terrestrial and marine records will ascertain the availability of the high-resolution integrated stratigraphic frameworks needed to realise the goals of the programme.

The information inferred from the terrestrial data bases and from the time-stratigraphic / palaeogeographic studies will create the basic framework for the *detailed analysis of palaeobiological patterns in time and space*, which, in turn, provides the basis for temporal and regional aspects of the reconstruction of terrestrial ecosystem change, collapse and recovery. A two-pronged approach will be adopted, involving studies of the High Resolution Intervals and investigations of the overall evolution of communities and environments. A comprehensive view of the global and regional climate record and the changes in the terrestrial environment in sufficient detail for each HRI is a major objective to be realised in order to ascertain the detection and understanding of ecosystem dynamics.

Working groups

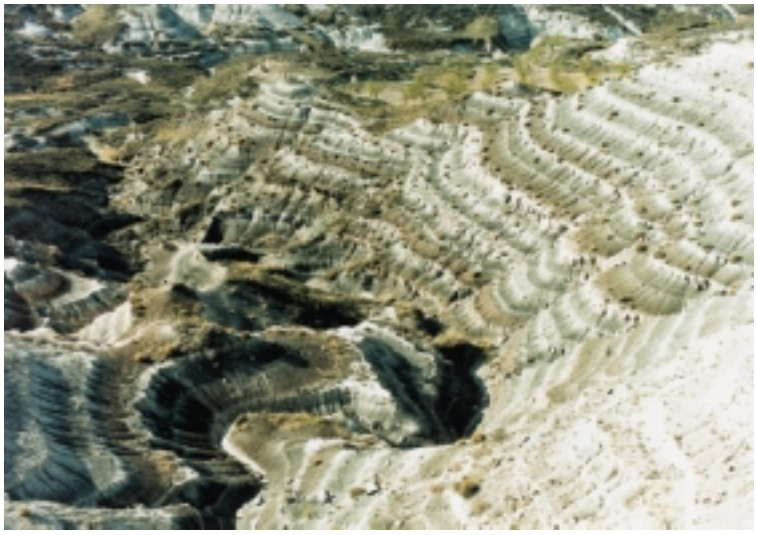
Four working groups have been established, which will be dedicated to specific themes pertinent to the EEDEN research strategy:

1. Working Group on vegetation history and climate reconstruction

The working group will promote and integrate research efforts on general reconstructions of overall trends in Neogene climate evolution as inferred from palaeobotanical/palynological records and, more specifically, focus on detailed reconstruction and modelling of regional climate patterns for the three High Resolution Intervals, along with the intercalibration of other terrestrial data and models with those obtained from the marine record. Vegetation reconstructions will provide the basic framework for ecosystem studies aiming at the understanding of plant – animal interaction. Wherever possible, the investigations will be based on the application of up-to-date quantitative approaches and it is envisaged that the results be linked with and elaborated in the context of, climate and ocean circulation models. Data and interpretations are to be combined in mutually compatible databases, which, in turn, will enable to ultimately construct regional climate / environment maps through the integration with the results provided by the working group on palaeogeography.

2. Working Group on mammal ecology and biodiversity

The working group will adopt a two-pronged approach, involving a) studies of selected High Resolution Intervals and b) "background" studies of overall evolution of communities and environments. Work will proceed from the analysis of distinct and well-documented changes to the testing of general hypotheses about the nature of ecosystem change. A key approach is the focus on ecological attributes of extinct species (i.e., the use of taxon-free ecomorphological information). Ecomorphological characterization of changes in faunas has a direct environmental interpretation and is relatively robust to the kind of sampling variation that plagues studies of diversity. Using occurrences across all localities (SPLOCs: SPecies Locality OCcurrences)) rather than conventional composite faunal lists will enable to incorporate information about changes in abundance and geographic distribution of taxa into our measures of biotic change. The statistical properties of the SPLOC-based measures will be investigated and the usefulness of SPLOC-analysis will be tested against real data on abundance data from well-sampled basins.



Precession-controlled, 20 Kyrs carbonate – mudstone cycles, Calatayud basin, Spain, portraying the degree of time-stratigraphic resolution that can be reached in Neogene terrestrial sequences.

3. Working Group on aquatic environments

The working group will investigate the structure and dynamics of aquatic environments through integrated studies of Lower Vertebrates (reptiles, amphibians, fishes), zoobenthos, phytoplankton and aquatic macroplants, aiming at the reconstruction of changes in the nature and composition of communities and at the characterisation of particular life-habitats. Research efforts pertaining to the three High Resolution Intervals will concentrate on biodiversity, trophic structure (unravelling the food web), complexity and function of selected freshwater ecosystems. It will be attempted to elaborate the interaction between changes in biodiversity and the dynamics of environmental evolution in terms of the response to climate change. This will be facilitated by incorporating taxon-free information (e.g., radioisotopic data) and results obtained from SPLOC studies, as well as by the integration with results inferred from the NOW and ETE data bases and those obtained by working groups 1,2 and 4.

4. Working Group on stratigraphy and palaeogeography

The working group aims at a) the establishment of a high-resolution time-stratigraphic framework for terrestrial sequences, b) the correlation of this framework with the astronomical time scale established for the marine record, c) the construction and improvement of large-scale (1:10.000.000) palinspastic / palaeogeographic – palaeonvironmental maps for the Tethyan domains and the bordering Peri-Tethyan platforms for the three High Resolution Intervals, and d) the construction of more detailed regional maps of selected key areas for the three HRI's. The high-resolution time-stratigraphic frameworks are to be based on the integration of up-to-date biochronology and the results of magnetostratigraphic and radioisotopic analyses, as well as on cyclostratigraphic studies based on the cyclic response of depositional environments to insolation changes coupled with orbital forcing in various frequency bands.

Workshops and funding

Annually, *plenary workshops* are envisaged which serve to integrate and elaborate the results of the four working groups and to firmly establish working plans for successive phases of realisation of the programme, which started in 2000 and will last until 2004. The first plenary workshop (Lyon, November 2000) was dedicated to the "state-of-the-art" with respect to stratigraphy/palaeogeography , terrestrial databases, climate evolution and palaebiological research, emphasising on the inventory of major problems pertaining to the three selected High Resolution Intervals.

Working group meetings will be organised by each working group at least once a year, prior to the plenary workshops. Subgroups of specialists are charged to answer specific questions relevant for the progress of the work in the respective research components. Activities of the working groups and the subgroups of experts not only concern the study of the three High Resolution Intervals, but also focus on tools and methodologies to be developed and on fundamental aspects regarding the interpretation of various proxy records. In 2000, three working group meetings were organised in respectively Helsinki, Parma and Lyon

The exchange of young scientists (including in particular Postdocs and

Ph.D. students) is promoted through a limited number of *travel grants*, meant to facilitate research visits to centres co-operating in the programme for periods of up to six weeks at the maximum. Detailed information on application guidelines and deadlines can be obtained from the ESF Secretariat or on the programme web site at http://www.esf.org/eeden. Applications should be submitted to the ESF Secretariat and will subsequently be examined by the Steering Committee in view of their added value with respect to the realisation of the programme's objectives. Priority will be given to applications by scientists from countries contributing to the EEDEN programme; financial arrangements will be set in accordance with ESF regulations.

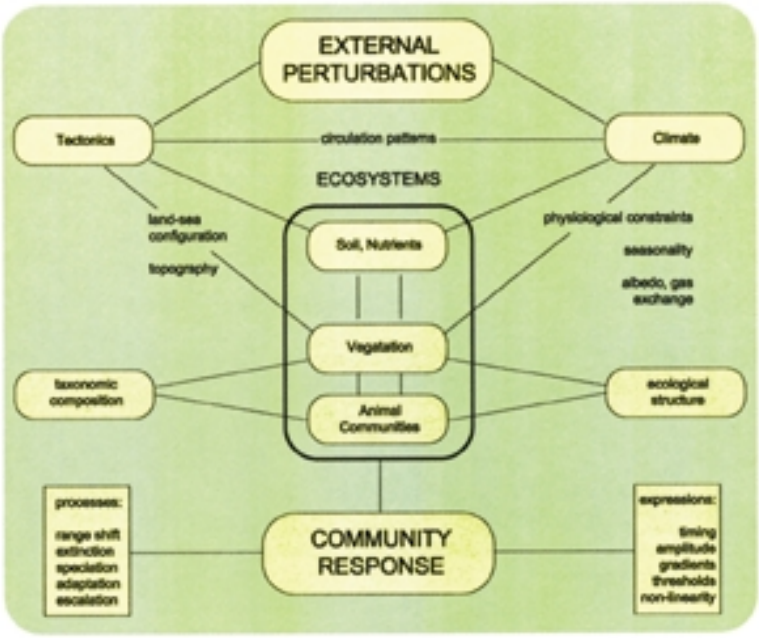


Diagram illustrating the complex interplay between various interacting components of terrestrial ecosystems and the effects of tectonic and climate forcing, determining community response to external perturbations.

Affiliation with other programmes

EEDEN is closely interconnected with and elaborates on the achievements of various European research efforts (partly) dedicated to the Neogene, such as NECLIME (Neogene Climate Evolution in Eurasia) , the NOW (Neogene of the Old World), ETE (Evolution of Terrestrial Ecosystems) electronic data base programmes, and the PERI-TETHYS Programme on palaeogeography and palaeoenvironments. Its goals are complementary to those of the IUGS Regional Committee on Mediterranean Neogene Stratigraphy (RCMNS) and to those of the planned IGCP programme on Correlation of Pathways of biodiversity and Environmental Challenges in Cenozoic Earth History.

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Cover picture: Persian paradise rug from Yazd, circa 1900

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