

EARTH SCIENCE EUROPE

A satellite-style map of Europe and the surrounding regions, including parts of North Africa, the Middle East, and Iceland. The map shows topographic features like mountains and rivers, and is color-coded by elevation and vegetation. The ocean is a deep blue.

DEVELOPING
EARTH SCIENCE
FOR EUROPE



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EARTH SCIENCE EUROPE

ESE is a grass-roots initiative. Through a process begun in October 2012, and subsequent actions, the solid-Earth science community has started to self-organize behind some key science initiatives, defining the infrastructure needs and overarching vision for solid-Earth science in Europe. ESE aims to provide a voice for the community in Europe, to promote collaboration across the research spectrum and in the translation of geological data and knowledge delivery. The community includes representatives of many European organizations and associations including EGU, EAGE, EuroGeoSurveys, EAG, European projects and programmes and research infrastructures, cutting-edge scientists in our field including ERC award-holders, and industry representatives. ESE has met formally twice, and held an online consultation in order to involve a greater proportion of the community and its stakeholders. This brochure is the first product of the initiative. *April 2014*

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Cover The face of Europe shown as a mosaic of true-colour land images taken by the Medium Resolution Imaging Spectrometer (MERIS) instrument on ESA's Envisat environmental satellite. ©ESA

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Earth science in Europe needs strategic decision-making, integrated research infrastructure and a strong voice, to address research and societal challenges and drive prosperity through innovation.



INTRODUCTION



Earth sciences support society, from discovery science to better management of our natural resources and geohazards. Earth Science Europe is a grass-roots initiative to unify Earth scientists and work together with other stakeholders for a safe and prosperous Europe.



“Earth-science related research services and products underpin much of our livelihood. Integration of the science base from research through government to the private sector is essential; Earth Science Europe plans to facilitate this”
John Ludden: Executive Director, British Geological Survey; Chair, Earth Science Europe



“Future demand for energy and natural resources requires new ideas about the subsurface. Earth Science Europe will help to provide geoscientists and engineers with innovative data and a diverse community for discussion. It will also inspire new generations to investigate the geosciences in years to come”
Gladys Gonzalez: President, EAGE



“Earth science data benefit society when fully exploited: accessed, aggregated, used and reused. We need interdisciplinary services for researchers and a roadmap to directly involve scientists and stake-holders in the grand challenges of the environment and human welfare: Earth Science Europe”
Massimo Cocco: INGV; EPOS Co-ordinator



“Earth science matters in our everyday lives, from safeguarding us from natural disasters, to supplying our growing population with energy and water. Pooling ideas about the dynamics of planet Earth – its chemistry, physics and biology, above and below the surface – is exactly the right tack to take, and Earth Science Europe is right on track!”
Brian Horsfield: Executive Director, ICDP



“Earth Science Europe is the next step towards integrating European research to address fundamental challenges concerning multi-scale Earth processes and societal challenges in, for instance, energy and georesources”
Sierd Cloetingh: Chair, TOPO-EUROPE Steering Committee; President, International Lithosphere Program; Member, Scientific Council ERC



“The ocean covers three quarters of our planet and plays a major role in natural resources and the climate. Recent breakthroughs at the interface between Earth sciences, biology, numerical modeling and climate research point the way forward. Not only is the present the key to the past, the past is key to our future”
Henk Brinkhuis: NIOZ



“As both data collection and research tools in the Earth sciences become more sophisticated, specialized and expensive, it is essential that we coordinate our resources across Europe in order to tackle the grand science challenges of the future”
Chris Ballentine: President, European Association of Geochemistry



“Society faces the grand challenge of ensuring human wellness and sustainability. We need to better understand the Earth system and human impacts on that system. Earth Science Europe will help us to reduce global environmental risks and sustain planetary resources”
Montserrat Torné: Director, Institute of Earth Sciences Jaume Almera; CSIC



“Earth sciences address major societal demands such as hazards mitigation and sustainable resources... but above all the human desire to always explore further and understand better our Earth, other planets and our origin. Earth Science Europe will help us progress along this path”
Michel Diament: Acting Director, CNRS-INSU



“Europe needs geological data, information, knowledge and expertise to address urgent societal challenges. Earth Science Europe can serve to strengthen the European research community across Earth science disciplines and sectors, from fundamental science to policy”
Mart van Bracht: President, EuroGeoSurveys



“Our affluent societies are at risk of forgetting the fragile balance of resources and dangers implicit in our natural environment, and the planetary forces which have brought them into being. Read on for a clear overview of the fundamental challenges, and the technologies we have to overcome them”
Donald Bruce Dingwell: Third Secretary General, ERC

EARTH SCIENCE EUROPE



Looking ahead Modern Earth-science research relies on innovative instruments for data collection, coupled with the infrastructure to combine and integrate varied types and sources of data.

Here we make the case for integrated Earth-science research across Europe, supporting society and industry through better management of natural resources and geohazard risks.

Earth science has the potential to inspire, protect and enrich the people of Europe. Earth science is the gateway to exploring the origin of our planet and the complex web of physical, chemical and biological processes that made and keep it habitable. Earth science is the key to managing the risks associated with natural hazards, especially in a changing climate. We need Earth science to find and safely use natural resources, to support prosperous societies and develop new industries to maintain economic growth.

In order to realize that potential, Earth scientists need to develop a comprehensive vision of the Earth, inside and out, as it changes through time. Modern computing methods mean that simulations of the Earth system in space and time are now feasible – and will drive innovative research.

INTEGRATED RESEARCH

Earth scientists now recognize that the evolution of our planet, our physical environment and life itself are intrinsically connected. As a result, research needs to be diverse and multidisciplinary; new observational technology, new methodologies for data collection and storage and collaborations across disciplines and countries, are needed – in short, a new research infrastructure across Europe. A new cooperative research model together with its necessary infrastructure will provide the framework for global-scale research success and enhance our

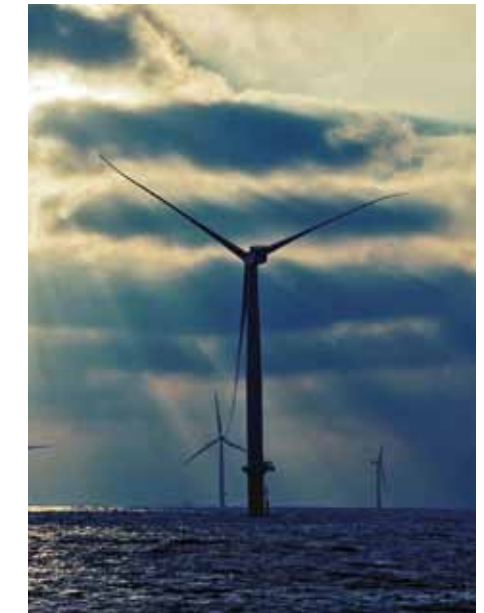
- Societies need to be safe from natural hazards, with reliable supplies of power and natural resources, in order to prosper



- Coordination of observations, data storage and analysis will enhance understanding of Europe's natural resources and hazards



- An integrated research infrastructure across Europe will foster authoritative communication of Earth-science information, to support society



ability to engage with challenges facing society, such as geohazards and energy supply in a changing climate. New ways of working that transcend borders will produce a capable, flexible workforce able to address big problems and bring solutions to business, industry and society.

The coordinated approach set out in this booklet will drive scientific solutions to the challenges facing society. Education and outreach are fundamental: inspirational research brings young people into technical careers; practical information enables informed decision-making throughout society. The aim is to build public confidence in the assessment of geohazards and management of their effects, and in renewing supplies of natural resources. The means to achieve this aim is the establishment of an authoritative science community that speaks with one voice: Earth Science Europe. ●

Above Society and business need reliable supplies of energy, whether from oil and gas or renewable sources such as geothermal and wind. Europe's energy balance will include all three in the next decades.

Right Flooding is just one of the natural hazards that Earth science can help to predict and it supports the development of strategies to avoid the worst effects.



THE BIG QUESTIONS



Cold snap Earth-science data must be collected in extreme environments such as the Arctic in order to gain a full understanding of the history of our planet.

● The origin of our planet and of life itself inspires awe and wonder in us all; Earth science explores these big questions

● Earth scientists study the past in order to understand the present and protect our future Earth

● Collaboration and joint research projects will enable successful European Earth-science research on the global stage

People wonder about the origin of the Earth, the universe and life itself. Earth science holds the key to discovering our origins.

Earth is a special planet. It is the only planet in the solar system with an oxygen atmosphere, oceans of water and a rich biosphere including intelligent life. We know of no planet like it, among the hundreds so far found around other stars. How did Earth form? When, where and how did life begin? How did life survive and thrive for thousands of millions of years?

GLOBAL CYCLES

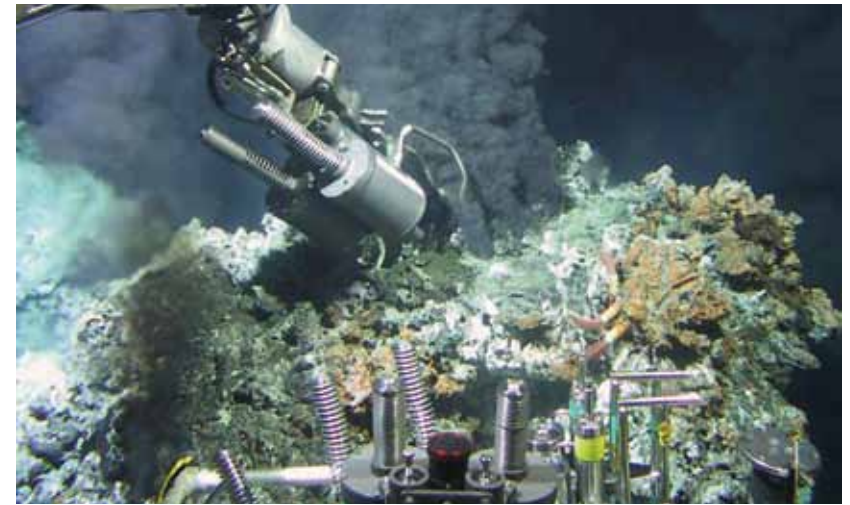
Earth scientists understand that our habitable environment today depends on complex interactions between the surface and deep Earth, through rock, soil, rivers, oceans and atmosphere. Our magnetic field – a shield against harmful radiation from space – owes its existence to the flow of molten iron in the Earth's core. We owe our unique atmosphere to gas released from the deep Earth by volcanoes; plate tectonics has helped to regulate our climate over millennia. Earth scientists investigate when these planet-scale connections began and how they interact.



Earth science combines traditional fieldwork with investigative technologies such as gravity surveys, deep drilling, geochemical mapping and geodetic surveys. This store of information about the origin, nature and evolution of Europe is revolutionizing how we see our planet – but it is also highlighting problems. New instruments and techniques for observations in remote and inaccessible sites such as the Arctic are improving data coverage across the continent, but gaps remain: on the seafloor, for example. Variable and incompatible data standards also limit progress. Procedures can vary from nation to nation and between disciplines such as geochemistry and geophysics.

Removing these barriers will streamline European Earth-science research.

The process has begun, with projects such as OneGeology and the European Geological Data Infrastructure programme, in which national geological surveys are working to harmonize data management. Closer research links and strategic planning will enable inspirational science and discoveries that evoke awe and wonder about the origin of life itself. Earth scientists across Europe, together, can achieve a deeper understanding of the processes that created our world. ●



Above Using a submersible to explore hydrothermal vents under the sea: perhaps the environment where life on Earth began.

Left Fossils such as trilobites tell Earth scientists about the environment at the surface of the Earth when they lived, hundreds of millions of years ago.

Below left From space, Earth is dominated by the greens and blues of life, unlike Mars or Venus. Understanding how this happened tells us about our origins and the prospects for life elsewhere in the universe.

EPOS: INTEGRATING SOLID-EARTH DATA

The European Plate Observing System is a framework for solid-Earth sciences research across Europe, an element of the European Strategy Forum on Research Infrastructures' roadmap. EPOS unites existing national solid-Earth research networks, linking satellite, seismic, surface dynamics, volcanic and oceanic observations with experimental and analytical laboratories, uniting researchers as a virtual community. EPOS works by integrating existing national infrastructures in ways that enhance access to the data and promote its use in innovative ways. While the links being developed by EPOS will benefit researchers initially, stakeholders in industry, business and society will also benefit.

WWW.EPOS-EU.ORG



THE DYNAMIC EARTH



Solid rock These distorted and folded rocks carry a record of past plate collision; today's tectonics alters geohazard risks.

- Earth's surface is dynamic, constantly changing as a result of both surface and deep Earth processes

- Deformation on human timescales alters both the risks and impacts of geohazards such as flooding and landslides

- Monitoring and imaging the Earth will enable modelling of the processes that shape our planet – now and in the future

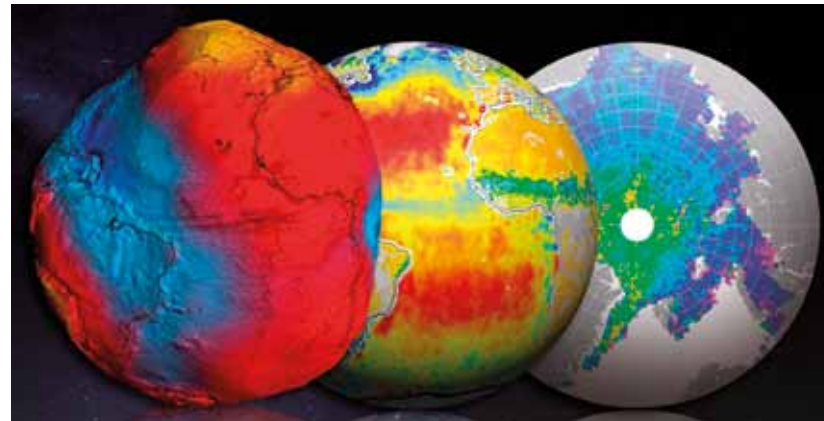
Changes to the shape of the Earth's surface affect our society on human timescales. Measuring and understanding deformation across Europe demands global Earth science.

The surface of the Earth is constantly changing its form and nature; on timescales ranging from months to millions of years, the surface bulges, subsides and shears. We live on this shifting surface; Earth scientists document the processes from the deep Earth that drive the constant movement and deformation at the surface.

The tectonic plates that make up the surface of the Earth move a few centimetres each year, ultimately as a result of convection in the deep Earth. Continental collisions produced great mountain ranges such as the Alps, contorting the rocks that built them. The constantly drifting jigsaw of plates brings stress and deformation to surface rocks in the form of earthquakes at plate edges. Subtler stress changes within the plates cause more than 60% of earthquake deaths worldwide – and much of Europe is at risk. Integrated observations of continental deformation using satellite data have proved powerful for mapping strain: radar interferometry can map distortions of just a few millimetres.

RISING AND SINKING

Slower landscape changes driven by land rising and sinking come about for many reasons and over a range of timescales: mountain building drives both uplift and subsidence over millions of years; glaciated regions rise for thousands of years



Above Maps of gravitational variation, soil moisture and ocean salinity plus Antarctic ice cover, demonstrating the power and global reach of European Space Agency satellite data.

after ice sheets melt; and water use by cities and industries can bring subsidence over decades. The steady weathering and erosion of highlands and the build-up of sediment in lowlands inexorably changes the topography and subsurface water flow. These changes, individually almost imperceptible, have consequences that include increased risk of catastrophic landslides and flooding.

Tectonic processes form the template on which life and society evolve. Climate, soil formation and erosion, and changes in biodiversity are fundamentally linked to the changing nature and form of the surface of the Earth. Integrative data collection and research, including environmental data such as biogeochemistry, will help to illuminate these connections.

At present, monitoring of these processes is patchy across Europe. Incompatible formats and data gaps impede fundamental understanding. An integrated approach to European Earth science will bring better understanding of the changes that affect the surface of the Earth, where we all live. ●

Left Sentinel-1, the first of Europe's new generation of environmental monitoring satellites, was launched in April to map distortions of the Earth's surface using radar.

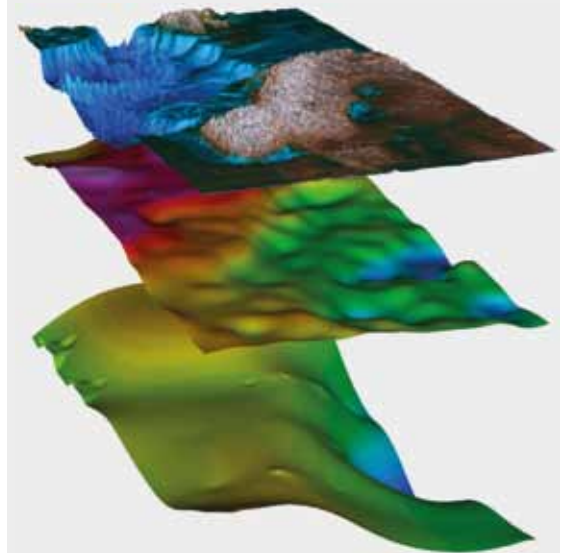
Right The shape of the continental margin off Norway (top), the base of the Earth's crust (middle) and the base of the rigid lithosphere (lowest), mapped using satellite geodesy and geophysics.

OUR SHIFTING SURFACE

Since 2005, an international collaboration called TOPO-EUROPE has been working to understand how and why the topography of Europe is changing – and what it means for European society. TOPO-EUROPE is a programme designed to describe the Earth system that determines the shape of our continent, monitor how it changes, predict its future evolution and evaluate how we can best live within that system.

TOPO-EUROPE is using Europe's mountain belts, sedimentary basins and continental margins as natural laboratories, bringing together Earth scientists with a broad range of expertise across geology, geophysics, geodesy and geotechnology. As well as mapping slow landscape changes, TOPO-EUROPE is assessing how they affect the risk of natural hazards.

WWW.TOPO-EUROPE.EU



A SAFE PLACE TO LIVE



Sleeping giant Millions of people live and work at risk from the effects of volcanic eruptions.

Everybody wants to live a safe and comfortable life. Earth science helps societies to achieve these aims, minimizing the impact of unavoidable natural hazards.

Europe's natural hazards include earthquakes, volcanic eruptions, landslides, catastrophic floods and storms, as well as global hazards such as tsunamis, asteroid impacts and solar storms. While hazards are inevitable, the worst of their consequences are not: loss of life and economic cost can be minimized. Earth scientists use past events combined with monitoring and modelling to assess potential risks from geohazards. This, combined with effective planning and governance, keeps people and businesses safe and boosts prosperity.

Earthquakes are a particular hazard in southern and eastern Europe. The SHARE consortium has taken a lead in collaborating on data standards and communicating the risk across national boundaries and in ways useful to national and European authorities (see panel, right). This risk-based approach is necessary because it is not possible to forecast exactly when and where a quake will occur; greater awareness of the science that determines the risk among governments and public authorities, as well as among the general public, will make societies safer.

BETTER RESILIENCE

Volcanic eruptions have been part of the history of Europe; they will be part of its future, too. More than two million people live close enough to Vesuvius to be at risk in an eruption; plumes of ash can disrupt international air travel, as happened from Eyjafjallajökull in 2010. Careful observation and

- **Earth science is essential for understanding the distribution and frequency of natural hazards**

- **Understanding geohazards helps us to mitigate their effects and develop effective disaster preparedness**

- **Climate change will alter our exposure to geohazards; future resilience will be enhanced by Earth-science knowledge**



monitoring allows hazardous volcanic activity to be anticipated; developing coherent observation campaigns for volcanic areas and wider regions at risk, then integrating the data with the work of civil protection organizations will improve Europe's resilience in the face of these hazards.

Such integration will also benefit Europe in the face of global hazards such as tsunamis and solar storms; infrastructure that enables global research will aid understanding of these hazards.

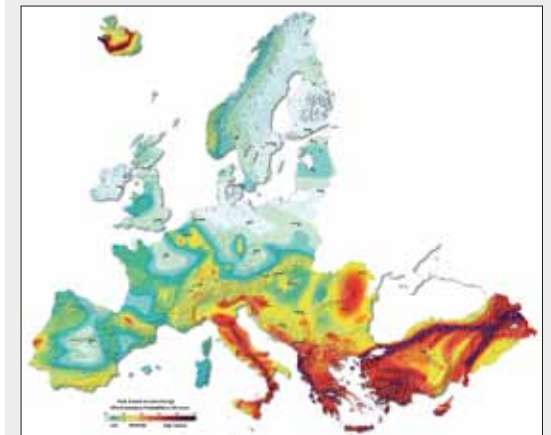
Better understanding of natural hazards such as catastrophic storms and floods will also improve resilience in the future. These events and their effects on human society are shaped by the landscape, which in turn is shaped by the surface dynamics of the Earth and by human activities such as construction, urbanization and industry. Earth science can examine and monitor these interactions and assess how a changing climate will affect the risks they pose to society. ●

Above This barrier in Zeeland, Holland, was built after the storm and tidal surge of 1953. Better understanding of the drivers of such events will support cost-effective and proactive flood defences.

Right The SHARE map shows regions of increased seismic hazard in red and brown. A pan-European approach to geohazard risks supports effective planning and regulation in all nations.

SHARE: SHARING KNOWLEDGE AND COMMUNICATING RISK

The SHARE project – Seismic Hazard Harmonization in Europe – began by harmonizing data and methodologies for assessing seismic hazards across the continent. These assessments are combined with modelling of the effects of expected earthquakes, using data from past events. This results in maps showing how likely it is that a certain level of ground shaking will be exceeded in the next 50 years, for example. This is essential for understanding the overall seismic risk. SHARE focused on the seismic hazard in order to support the development of both European and national standards for mitigation of their effects. With the harmonized assessment of seismic risk provided by SHARE, national and European authorities can set in place earthquake engineering standards at suitable levels to protect homes and the more stringent requirements for critical infrastructure such as hospitals and power plants. WWW.SHARE-EU.ORG



LIVING ON PLANET EARTH

Water power Water is a valuable resource, for society, for industry and, as here in Hamburg, a valuable civic amenity. A secure supply is a priority for Europe's increasingly urban society.



Successful societies need resources: water, energy and raw materials.

Earth science is the foundation of the exploration and responsible use of Europe's natural resources.

Europe has abundant natural resources. Yet a populous continent puts increasing demands on living space, water and energy supply, as well as mineral resources. And new technologies require secure supplies of new groups of resources; advances in healthcare demand new biomedical resources derived from subsurface microbes, for example. Earth science underpins the supply of resources; it determines how best to exploit them responsibly and to manage waste responsibly. It also helps to control the effects of society as a geological force; human activities such as farming, mining and urbanization increasingly change our planet.

Understanding the surface and subsurface is the key to discovering and managing resources such as water. Research drilling allows investigation of this near-surface region, including unusual and potentially valuable microbes. Sediment records from boreholes are a treasure trove of information about past climates. Chemical exchanges between atmosphere, seas, rivers and rocks drive or limit greenhouse gas accumulation



● **Safe, clean water supplies rely on knowledge and understanding of the Earth's near-surface cycles**

● **Understanding how mineral deposits form will help to find new sources of economically important minerals**

● **Future water and energy security depends on a solid understanding of Earth science across Europe**

in the atmosphere; understanding them is part of managing global change.

Understanding the movements of elements between the deep Earth and the surface is a major step towards finding new mineral resources. New technologies need rare-earth and platinum-group elements, for example, elements not considered in traditional models of ore formation; a new research effort to understand how they are concentrated by geological processes will reveal new resources for Europe, benefiting current and future industry.

ENERGY FOR ALL

Society and industry need energy; reliable supplies will demand a mix of sources including geothermal and other renewables alongside fossil fuels and nuclear energy in the coming decades. Europe needs Earth science to find, develop and exploit new sources of energy and the energy technologies that will power the future. Safe handling of waste, to minimize environmental impact, is part of the global energy challenge; radioactive waste especially needs safe storage over geological timescales. Sequestration of carbon dioxide may prove to be part of the balance between fossil fuel use and climate protection.

All these issues gain importance in the face of growing human activities and population. A society that is secure in its energy supply, with ample water resources and access to natural resources to drive new industry, relies on Earth science. ●



Above An ICDP drill ship at work in the Dead Sea. Both cores of rock and the records of fluid flow and composition are valuable for exploring the subsurface and the minerals and even life-forms it holds.

Left Stibnite, the main ore mineral of antimony, is among the minerals that are driving new technological industries. Discoveries of new mineral resources within Europe will support industrial success in the future.

GOING DEEPER FOR RESEARCH

Borehole drilling is a powerful research tool. The European Consortium for Ocean Research Drilling (ECORD) coordinates seafloor drilling across Europe with the global International Ocean Discovery Program (IODP). Drilling on land is organized via the International Continental Drilling Program (ICDP). The data from these programmes help scientists to understand the evolution of Europe in a global context. Scientific links and technological synergies between ocean and continental drilling have built a strong research community; further integration across Europe will boost research capabilities.

Commercial drilling is important in the hydrocarbons industry; research drilling complements their work, but also provides more complete data coverage. In addition, it provides the information needed for governments and the public to ensure fair, responsible and safe exploitation of the raw materials Europe needs.

WWW.ECORD.ORG | WWW.IODP.ORG | WWW.ICDP.ORG

DRIVING EUROPEAN GROWTH

A nighttime photograph of the Glasgow Science Centre. The building features a prominent, curved, metallic structure with a large glass facade. In the foreground, a curved walkway with a metal railing runs alongside a body of water. The scene is illuminated by warm, orange-toned lights, creating a modern and architectural atmosphere.

The Glasgow Science Centre is on a site that was once a cargo port and offers a model for urban redevelopment elsewhere. Research into the local subsurface suggests that there is enough ground-source heat to provide Glasgow with low-carbon energy for at least 100 years.

- **Earth science is needed to discover the raw materials to drive economic growth, and to manage their safe exploitation**

- **A secure and diverse energy supply demands Earth-science expertise to develop sustainable new resources**

- **Active research produces innovative instruments and methods that drive new technological industries**

It takes Earth science to find the raw materials, water and energy resources that build economic prosperity, support Europe's industries and promote innovative technologies.

Europe is a diverse continent, geologically, industrially and socially. In order to harness Earth science for growth, we need coordinated international research to underpin the discovery and development of natural resources and promote sustainable industries, cities and societies.

Economic prosperity depends fundamentally on natural resources. Accessible integrated Earth-science data across Europe will allow efficient use of known resources and pinpoint new sources. Construction, whether of housing, transport or industrial infrastructure, relies on Earth science for the necessary minerals, aggregates and hydrocarbons. And it is Earth science that provides the tools for ensuring safe and responsible extraction, through site-specific or remote monitoring and regulation. Many of the tools now used for assessment of the environmental impact of a quarry or mine are also used for site investigation ahead of construction projects. Increasingly, geophysical and remote-sensing methods are reducing the cost and increasing the effectiveness of subsurface investigation.

SAFE INFRASTRUCTURE

The risk from geohazards is an important element of decision-making about the location and design of vital infrastructure: transport, power generation, information transfer. Both the insurance industry and those seeking protection for their assets would benefit from an integrated Earth-science approach.



While Europe has established sources of oil and gas, for example, our future use of them in a crowded continent demands public support. Integrated European resource-mapping will support political decision-making. Earth-science research can also support safe treatment of waste and effective restoration of the landscape, promoting sustainable mining and quarrying.

Fossil fuels will continue to be part of Europe's energy mix in the coming decades. Schemes to isolate the resulting greenhouse gas carbon dioxide from the atmosphere use Earth-science techniques. Earth science also underpins other elements of a mixed-energy economy: radioactive waste storage and raw materials essential for current and future renewable energy technologies, including thermal reservoirs.

Development of a common research infrastructure will bring innovations that will readily transfer to industry. Earth scientists are already using facilities such as the European Synchrotron particle accelerator to solve Earth-science problems; these technologies and the skilled people who use them will boost business in Europe. ●

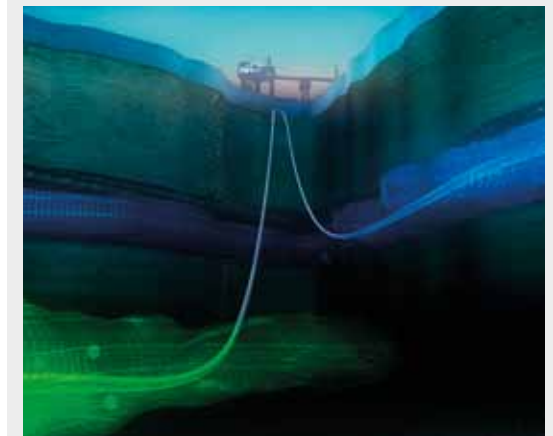
Above Whether it is building stone, stone for decoration, aggregate for construction, or minerals and ores for new technologies, quarrying provides the raw materials that drive growth.

Right Carbon capture and storage underground. About a million tonnes of CO₂ is pumped into rock every year at the Sleipner East field beneath the North Sea, using CO₂ capture technology developed as part of the gas field development.

GOING WITH THE SUBSURFACE FLOW

Much of the energy sector depends on monitoring and understanding processes in the subsurface: extraction of coal, oil, gas and shale gas, carbon capture and storage, nuclear waste storage and geothermal energy. Low-carbon options for energy supply, carbon capture and storage schemes in particular, rely on long-term management of subsurface processes to keep greenhouse gases out of the atmosphere.

All these energy supply options depend on new research infrastructure allowing sustained monitoring on human timescales. This will act as a bridge between research and application in the energy sector and build connections between research and industry. It will include EPOS and the European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL), for example, together with *in situ* monitoring including deep boreholes, combined with satellite measurements. WWW.ECCSEL.ORG



INSPIRATION AND INFORMATION

A female scientist in a laboratory setting, wearing safety goggles and a head-mounted display (HMD). She is looking intently at a piece of scientific equipment, possibly a microfluidics or lab-on-a-chip device, which features several glass flasks or chambers. The background is slightly blurred, showing other laboratory equipment and a clean, professional environment.

Look closely Earth scientists gain technical skills, innovation, and a problem-solving approach - attributes that benefit industry and business, too.

- **Better international and multidisciplinary links within Earth science will build a skilled and flexible workforce**
- **Inspirational Earth-science research will raise the profile of Earth science and draw young people into science**
- **Targeted Earth-science information for the public and professions will inform decision-making in society as a whole**

A unified voice for Earth science in Europe will inspire the next generation of scientists and clarify communication with European-level decision makers – and foster a technically skilled workforce.

Europe has a strong research culture. Successful research inspires people of all ages, encouraging the next generation of scientists and helping a scientifically literate public to use Earth science to better their lives. European Earth scientists – working together, making Earth science accessible, speaking with one voice – will provide accessible, relevant information to promote our subject and support business, industry and education.

Integrated European programmes will help establish research centres in nations without a tradition of Earth-science excellence, bringing greater mobility for research staff. A lively and successful research culture brings innovative ideas that spread into new technological industries. And a strong research community brings technically skilled people to work in careers that support society, in industry, public safety and education.

THE FUTURE GENERATION

Our planet and its history inspires and intrigues people, especially the young – the next generation that is essential for a thriving research community in the future. Finding fossils and minerals shows children that they can make discoveries. But it is important to demonstrate that Earth science involves much more than collecting rocks. Accessible Earth-science information, reflecting a thriving European research community, can inspire young people to choose scientific careers; it also



encourages people to choose Earth science as a hobby, boosting scientific literacy in society.

All nations in Europe face difficult decisions in order to maintain the safety and prosperity of their citizens; resources, geohazards and energy supply are all under pressure. A higher level of Earth-science knowledge among authorities, educators, business and public officials will lead to more effective governance. Understanding history, including the history of our planet, will inform decisions regarding our future. Better training for professionals will support individuals in their careers while boosting the role of Earth science in public life.

Earth scientists, working together in research across Europe, have the authority that a safe and prosperous Europe needs. We can inspire and educate the Europeans of the future. Speaking with one voice, we can provide an accessible, integrated source of Earth-science information across Europe that will benefit science and society alike through more effective transmission of necessary Earth-science information to those who need to know. ●

Above Getting their hands on the past – here a dinosaur bone – can inspire children to think about the future. These could be the Earth scientists of the 2020s.

Right Earthquakes destroy lives and livelihoods. Individuals and policymakers need information that they can use in order to make effective choices about the risk from natural hazards.

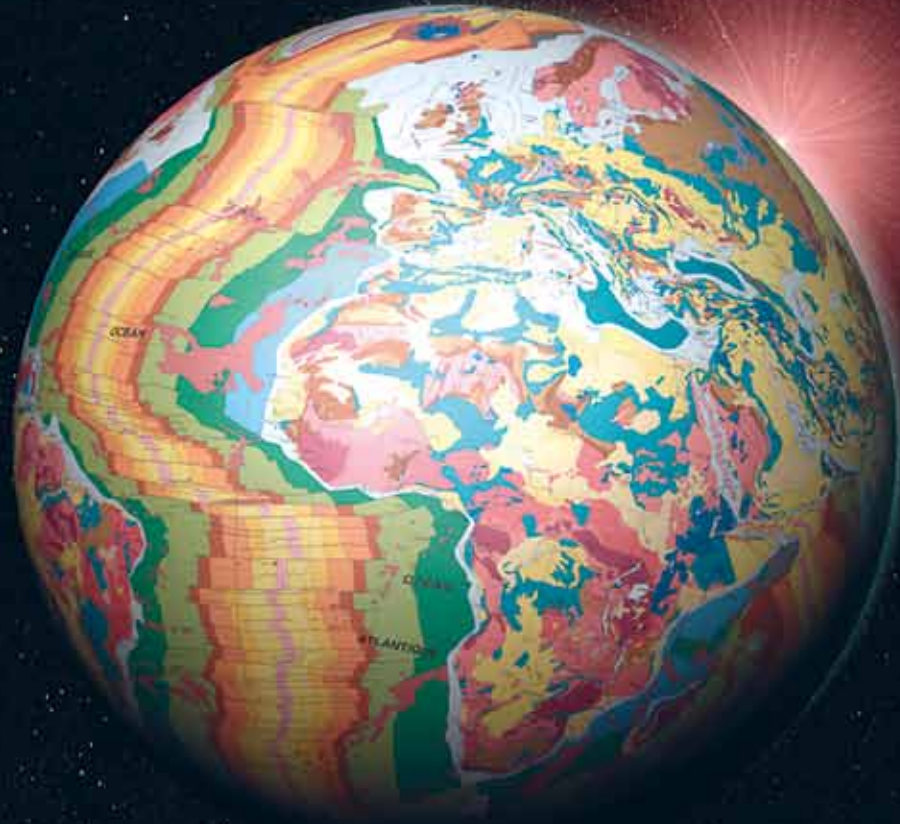
COMMUNICATING RISK

Education and public outreach is a growing field for many researchers. But in Earth sciences (and environmental sciences in general) it is important to distinguish between communicating science and communicating risk. Communicating the risk to society from geohazards requires a clear understanding of the resilience of local communities as well as an appreciation of how individuals assimilate and apply scientific information about risk and personal exposure.

Risk communication does not involve the scientific community alone – different roles are needed in order to develop effective strategies in the light of these complex ethical issues. Cross-disciplinary collaboration is required to tackle the challenge of helping local communities and individuals in making their own behavioural choices as well as supporting policymakers to manage prevention and emergency planning.



THE NEXT STEPS



Ultimate Earth The OneGeology dynamic digital map project is an example of good practice in global spatial data infrastructure, recognized by GEO, UNESCO, IUGS and ICSU.



Earth science in Europe needs strategic decision-making, integrated research infrastructure and a strong voice, to address research and societal challenges and drive prosperity through innovation.

Earth scientists need a unified, authoritative voice to enhance the status and impact of Earth science across Europe. The first step is to establish Earth Science Europe as a coherent coordinating framework for the Earth-science community. Then comes a robust research infrastructure to deliver strategic goals, enabling inspirational research and promoting solutions to societal challenges.

INTEGRATING RESEARCH

Earth Science Europe will develop strategic research capacity through a roadmap addressing fundamental and societal challenges. This will build on science challenges of national research programmes and to deliver the Horizon 2020 programme.

BUILDING INFRASTRUCTURE

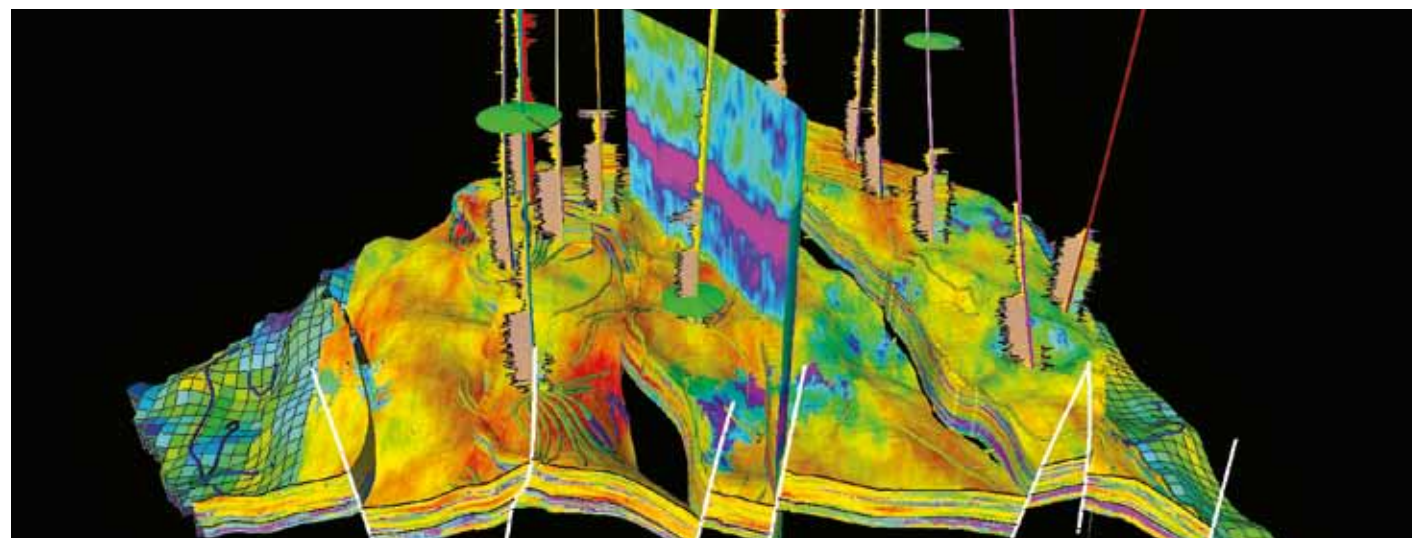
This collaborative approach demands the renewal and growth of research infrastructure, shaped around national, pan-European and cross-disciplinary collaborations.

- Establish common standards for data and sample storage and exchange.
- Develop new shared ways of working that provide new discoveries and boost innovation.
- Make international shared facilities the norm, for efficiency and to promote exchange of ideas.

SHARING INFORMATION

Earth Science Europe will bring a stronger, more connected community that looks outwards, engaging with stakeholders across society and speaking together, with authority.

- Work more closely with stakeholders.
- Boost public understanding of Earth science, especially resource management and geohazards.



- Develop and share inspirational outreach for young people, our future scientists.
- Promote and monitor gender balance in research teams and decision-making.

DRIVING INNOVATION

Modern sensors allied to advanced research methods will give a new and detailed picture of Europe's geology and, aligned with other environmental surveys, will transform geological and environmental understanding – providing the capability to visualize and model aspects of our Earth in many dimensions.

This new integrated geological understanding of Europe will enable better global understanding of geohazards, georesources and environmental security. These are the essential steps needed for Earth science to support the secure, prosperous European society of the future.

WWW.EARTHSCIENCEEUROPE.ORG

Big data Advances in seismic imaging and 3D subsurface modelling technology provide new insights into subsurface energy resources. Similar techniques make it easier to examine large datasets from diverse sources and to share knowledge and expertise from varied fields – boosting innovation across Europe.

EUROPE 2020, HORIZON 2020



The European Union's strategy Europe 2020 identifies smart, sustainable and inclusive growth as a key goal over the next decade. Horizon 2020 explicitly aims to secure these goals and Europe's global competitiveness through funding research in key areas. The Horizon 2020 objectives are a good fit for Earth-science priorities, including data infrastructure, energy and climate, as well as an emphasis on strengthening the links between science and society. In turn, Horizon 2020 will support the development of a more equal, gender-balanced scientific community. Horizon 2020 offers an opportunity to establish Earth science as the bedrock of European prosperity in the decades to come.

EC.EUROPA.EU/PROGRAMMES/HORIZON2020

“**PEOPLE LIKE TO DREAM** about the origin of the Earth, the universe and life itself

PEOPLE NEED TO BE SAFE from natural hazards, especially catastrophic events

PEOPLE WANT TO BE COMFORTABLE, to have a secure supply of energy, water and raw materials

EARTH-SCIENCE RESEARCH helps underpin all of this”

THE EARTH SCIENCE EUROPE COMMUNITY MISSION:

“To make new discoveries and inspiration to better understand the history and internal dynamics of our planet, and to provide society with data, manage knowledge better and live more wisely on our planet”

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