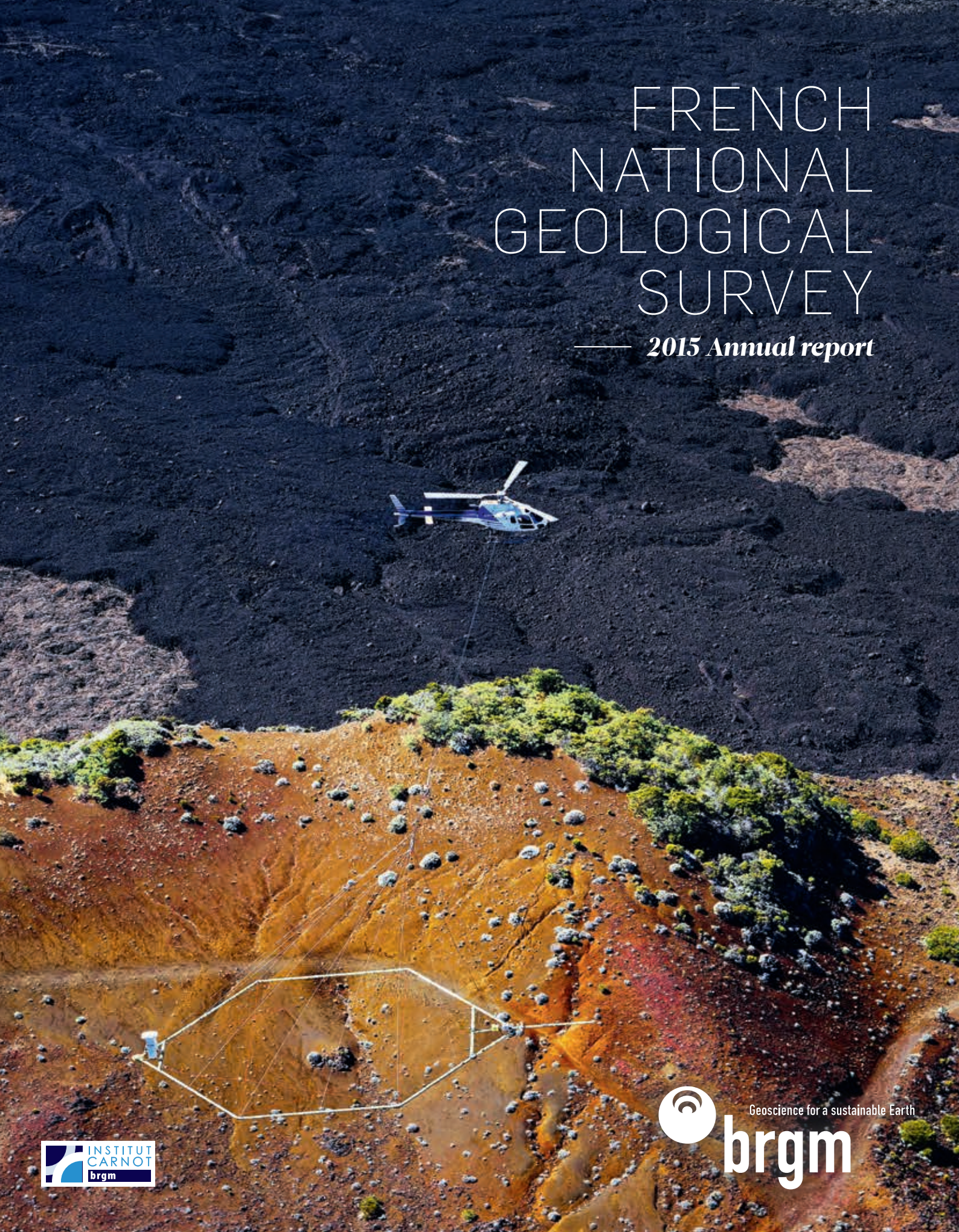


FRENCH NATIONAL GEOLOGICAL SURVEY

2015 Annual report

Geoscience for a sustainable Earth

brgm

INSTITUT CARNOT brgm

CONTENTS

Geoscience for a sustainable Earth

brgm

THE BRGM IS THE FRENCH GEOLOGICAL SURVEY ORGANISATION AND FRANCE'S LEADING PUBLIC INSTITUTION FOR EARTH SCIENCE APPLICATIONS FOR THE MANAGEMENT OF SURFACE AND SUBSURFACE RESOURCES AND RISKS. ITS ACTIVITIES ARE GEARED TO SCIENTIFIC RESEARCH, SUPPORT TO PUBLIC POLICY DEVELOPMENT AND INTERNATIONAL COOPERATION.

UNDERSTANDING
geological phenomena and associated risks

DEVELOPING
new methodologies and techniques

PRODUCING AND DISTRIBUTING
data to support the management of soils, subsoils and their resources

DELIVERING
essential tools to support soil, subsoil and resource management and policy development on pollution, risk prevention and climate change.

+7.81 M€
2015 OPERATING RESULT

191
SCIENTIFIC PAPERS PUBLISHED IN *CLASS A* JOURNALS IN 2015

1035
PEOPLE WORKING FOR THE BRGM INCLUDING OVER 700 RESEARCHERS AND ENGINEERS

ANNUAL REPORT 2015

"The geosciences and the BRGM are in a position to make major contributions to meet the challenges of climate change adaptation and the energy transition"

Vincent LAFLÈCHE
BRGM Chairman and Executive Director

The year 2015 ended with the impressive undertakings announced by COP21. Whether in the field of spatial planning to adapt to climate change or in the energy transition context, events in 2015 have clearly strengthened the view that the geosciences, and the BRGM in particular, have a vital role to play in meeting these challenges. The RGF, or French Geological Reference Platform, a flagship programme run by the BRGM, is in a position to make major contributions in the field of "predictive geoscience". One consequence of the spectacular drop in raw materials prices has been a slowdown in mineral exploration and in the development of a circular economy, although medium and long-term trends for many metals and minerals are still on the rise. Many observers anticipate an abrupt reversal of the current slowdown, which would trigger considerable market tension in some areas. Research projects on the circular economy, and several important contracts concluded with the BRGM for geological mapping, with a focus on the mining potential of African countries, reflect a certain amount of optimism at this stage among mainly public players. Meanwhile, the REMETOX project (on the recovery of valuable metals from e-cards using super-critical water), winner of the Phase 2 award in the World Innovation Competition 2030, is moving into the pilot technological assessment stage, with the aim of validating processes that will open the way to industrialisation.

These major issues for our society are creating needs for new knowledge and new tools, thus bringing new scientific challenges. Several awards and other forms of recognition have confirmed the onward progress of scientific excellence at the BRGM: examples are the increase in publications and the appointment of two BRGM staff members as associate editors of two prestigious scientific journals (Geochimica Cosmochimica Acta and American Mineralogist). Also to be noted is the significant increase in BRGM guest speakers and chairs of conference sessions (39 in 2014, 70 in 2015).

Making contributions also means matching our programmes more closely to the expectations of all stakeholders and economic players, especially in BRGM Carnot Institute programmes. The very positive feedback we are getting from the companies we have been meeting with more regularly since the creation of our Development Division in 2014 shows that the BRGM's scientific and technological potential was not always sufficiently visible, and is an encouragement to pursue this policy.

With the transfer of competences to the Regions under the territorial reform introduced by the NOTRe* Act of 7 August 2015, especially for spatial planning and climate change adaptation, new needs have emerged as well as new players such as intermunicipal water management bodies. The territorial reform has thus raised the significant challenge of adapting the BRGM's organisational structure to meet increasing local government needs for new tools and knowledge, as part of our key role of supporting public policy development.

The decision made by the BRGM's Board of Directors to transfer its head offices from Paris to Orléans illus-

trates our intention, as the national geological survey organisation, to reinforce our role in promoting development in the new Centre-Val de Loire Region. The economic support announced by the regional authority is of great importance for the BRGM's multiannual scientific investment plan, also adopted by the Board of Directors. Renovation of our pilot experimental facility is essential to reinforce the geosciences centre in Orléans, with the BRGM and its partners - academics from the Orléans campus and business R&D teams - operating at the hub.

In 2015, the BRGM also pursued its commitments to partnerships in other regions in specific topic areas. The Dem'eaux project, for example, selected by and conducted with the CPER for the Languedoc Roussillon Midi Pyrénées Region to further knowledge on complex karstic or multilayer aquifers, illustrates the potential of established thematic teams to contribute to our regional specialisation strategy (3S). Establishing new research teams to work closely with our partners in other regions is clearly a topic to be addressed in our preparations for the next performance contract, which will begin in the second half of 2016.

Finally, the BRGM continued to work in two areas to which I am particularly attached. Around a dozen meetings organised by our regional divisions with consumer and environmental associations proved to be of great mutual benefit. The pilot implementation of our professional ethics scheme was very well received by BRGM staff. Our ethics committee identified and investigated more cases than expected, bringing up long-standing questions that had not been expressed before for lack of suitable channels. These activities can only help to support the BRGM's reputation as a credible - and audible - source of expertise which is fully aware of its vocation to contribute, as a public organisation, to the necessary public debates that the challenges we collectively face will inevitable raise.

**NOTRe: Nouvelle organisation territoriale de la République*

2015 IN PICTURES

16 FEBRUARY

Inauguration of the LC-TOF

Inauguration of the new LC-TOF high resolution spectrometer at the BRGM laboratories, in the presence of Vincent Laflèche, BRGM Chairman and CEO, José Portella, sales engineer for chromatography and mass spectrometry, representing Alain FAVRE, the Managing Director of Waters, François Bonneau, President of the Centre-Val-de-Loire Region and Michel Jau, Prefect of the Centre-Val-de-Loire Region.

© BRGM - ALAIN CANON

23 APRIL

ASTER project closing conference

Presentation in Orléans of the results of the ASTER project (Systems Analysis of Rare Earths - flows and stocks) launched in 2012, which involved about one hundred researchers and aimed to quantify the flows of certain rare earths in Europe along their entire value chain.

© BRGM - NOLWENN HERVIO

10 SEPTEMBER

Inauguration of the Vouters pumping station

Inauguration of the pumping station and mine water treatment station installed on behalf of the State at the former Vouters mine at Freyming-Merlebach (57). Mine water is pumped out from the Vouters pit to lower the amplitude of groundwater rise, and treated prior to its release into the natural environment. This innovative and environmentally compatible system is the third, and last, of its kind to be installed in the Lorraine coal basin.

© JEAN-MARIE GUZIK

10 - 11 JUNE

Visit from an ICGC delegation (Catalan Cartographic and Geological Institute)

Signature of a cooperation agreement between the ICGC and the BRGM, in the presence of ICGC managing director Jaume Miranda and management team members Joan Sendra, Antoni Roca and Xavier Berastegui.

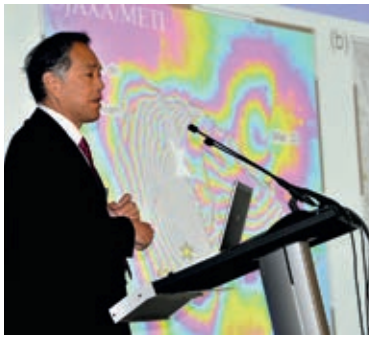
© BRGM - NOLWENN HERVIO

16 - 18 SEPTEMBER

Franco-Japanese symposium on earthquakes and attendant risks

This Franco-Japanese symposium was organised by the BRGM, in cooperation with the DPRI (Kyoto, Japan), as a meeting for scientists from all countries with an interest in seismic risks and attendant phenomena. It was attended by 75 scientists from more than 30 institutes in 10 different countries.

© BRGM - NOLWENN HERVIO



21 - 25 SEPTEMBER

AIG11 - International Applied Isotope Geochemistry Congress

The 11th International Congress on Applied Isotope Geochemistry (AIG-11) was held in France. For the second time since 1999, the BRGM hosted the AIG congress, which was attended by over 150 participants. The scientific topics discussed ranged widely across different fields including environmental geochemistry, water resources, palaeoclimatology and palaeoenvironments, biogeochemistry, high-temperature geochemical processes, the geochemistry of sediments, hydrocarbon extraction, medical and food security applications, new analytical developments, etc.

© BRGM - NOLWENN HERVIO

2015 IN PICTURES

23 SEPTEMBER

10th edition of the CARNOT Meetings on research for businesses and local government, in Paris

The BRGM took part in the Carnot Institutes 10th anniversary celebrations. The BRGM Carnot Institute presented two examples of successful partnerships for scientific and technological innovation.

© Ai Carnot

9 - 13 OCTOBER

2015 Science Festival at INRA

An interactive demonstration of the use of drones for gravitational risk prevention studies, at the 2015 Science Festival at INRA.

© BRGM - BÉNÉDICTE PESSET

14 OCTOBER

Celebrating the BRGM's 50th anniversary in Orléans

For its 50th anniversary celebrations on 14 October 2015, the BRGM hosted almost one hundred local public and private partners at its scientific centre. The event was an opportunity for the participants to discuss their working relationships with the French geological survey organisation. The BRGM and the Loire-Brittany Water Agency (AELB) also renewed their partnership agreement on the same occasion.

© BRGM - DIDIER DEPOORTER

2015 IN PICTURES

21 - 23 OCTOBER

SIM Congress at Mons in Belgium

*The BRGM took part in the SIM Congress (*Société de l'Industrie Minérale*), an essential venue for professionals in mining, quarrying, cement, industrial minerals and recycling platforms. At the event, which took place in Mons in Belgium, the BRGM presented its activities on strategic metals and mineral economics. During the congress, the BRGM, UNICEM and SIM presented the map of quarries and industrial minerals in France.*

© BRGM - BENOÎT GAYET

6 NOVEMBER

Signature of the BRGM-Total partnership agreement at Total's head offices at La Défense in Paris

Daniel Plathey, Director for R&D with Total Exploration & Production, and Vincent Laflèche, Chairman of the BRGM, signed a strategic agreement on the organisation of their common research areas in geology. The aim is to set out a clear and coherent framework for cooperation in the next five years.

© BRGM - BENOÎT GAYET

2 - 7 NOVEMBER

Provins Forum on Climate

The BRGM took part in the 12th edition, focusing on climate and organised under the banner of the 21st United Nations Conference on Climate Change (COP21).

© FORUM DE PROVINS

18 - 19 NOVEMBER

The 2015 Carnot Meetings in Paris (Les Docks, Cité de la Mode et du Design)

The BRGM, as one of the Carnot Institutes, took part in the Carnot Meetings on Research and Development for business.

© Ai Carnot

2015 IN PICTURES

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

30 NOVEMBER - 11 DECEMBER

COP21 Climate change solutions and innovations - Exhibition at the Grand Palais

The BRGM took part in the 21st United Nations Conference on Climate Change (COP21), held in Paris from 30 November to 11 December 2015. It contributed to several events addressing climate change, including the COP21 Solutions event in the "Research and Climate Pavilion" at the Grand Palais.

TOTAL
COMMITTED TO BETTER ENERGY

INTERVIEW

DANIEL PLATHEY
Research and Development Director, Total Exploration & Production

Ramping up research on geological topics of common interest

In 2015, Total and the BRGM signed a strategic framework agreement, named "*Convergence*", to organise common research on certain geological phenomena involved in the formation of fossil fuel deposits. The agreement also marks a new phase to consolidate and strengthen a long-standing and well-established partnership.

What are the main issues addressed by this strengthened cooperation on geology research?

Like other numerous and sometimes long-standing research partnerships with the BRGM, the 5-year *Convergence* agreement, signed on 21 December 2015, has an ambitious goal: to apply innovative geological concepts to better understand the mountain range dynamics involved in the formation of sedimentary basins that potentially contain hydrocarbon deposits. The scientific knowledge gained could, in time, help Total to improve its exploration strategies to uncover new deposits and optimise the conditions of resource extraction.

The *Convergence* agreement reflects long-standing collaboration on geology between our two organisations, which we are ramping up in response to developments in the last ten years. Challenges to the geological concepts on which prospecting has been based until now demand a reappraisal of more fundamental geological knowledge to support more efficient prospecting in the future. By undertaking research further upstream, we hope to develop new approaches. To give a concrete example, the sedimentary basins involved in the formation of mountain ranges have significant residual potential for oil exploration that could also reduce extraction costs and open up prospects for diversification into deep offshore explorations. The innovation in the *Convergence* programme lies in studying these basins as part of an overall geodynamic system, taking the evolution of their deeper structure into account.

The launch of *Convergence* thus reflects our decision to pursue and strengthen our collaboration with the BRGM within an overall framework of more ambitious scientific research, the intention being to focus primarily on major partners while opening up to academic institutions. The BRGM was a natural choice, given its reference status in the

© LAURENT PASCAL

"The key issue is to develop new ideas through upstream research."

Daniel PLATHEY
Research and Development Director
with Total Exploration & Production

geoscience field in France and internationally. The BRGM's areas of competence are crucially important to studies of the phenomena that Total wishes to investigate, and its status makes it possible to forge methodological links with public research. The *Convergence* agreement therefore sets out a strategic framework for cooperation that can potentially cover a variety of projects and involve third parties as partners (universities, CNRS, etc.).

The fact that the BRGM is in charge of the RGF (French Geological Reference Platform), with work currently focusing on the Pyrenees, opens up an opportunity for studies of the Aquitaine basin, the "birthplace" of Total, if you will, to better understand the role of the Pyrenees range in the formation of petroleum deposits in the region. Thanks to a more scientific understanding of the phenomena involved, we will be able to draw important conclusions to prepare for future explorations around the world. For Total, these studies will represent a laboratory for explorations in mountain ranges, using an innovative approach applied for the first time in our industry.

What are the main research topics that Total and the BRGM have in common?

There are many. Internationally, for example, they concern projects such as the one for which Total Exploration & Production, the main oil company operating in the Republic of Congo, has called on the BRGM for assistance with our support to the development of the country's geological infrastructure. The aim is to organise a geological mapping campaign and a field course for 2nd year Master's students at the geology faculty of Marien N'Gouabi University in Brazzaville.

Another example is the ANR Biophy project on hydrocarbon depollution using non-destructive methods to monitor hydrocarbon depollution by biological processes. Biophy, an ANR project piloted by BRGM, set out to improve classic methods for monitoring bio-depollution of hydrocarbons through geophysical measurements and gas analyses.

Finally, Total has benefited from BRGM research on the use of highly saline aqueous environments: deep saline aquifers are a source of heat that can be extracted for geothermal energy, and can also be used as reservoirs to store substances such as excess CO_2. This is in line with our group strategy as set out just recently by our Chairman.

45

RESEARCHERS WORKING UNDER THE CONVERGENCE AGREEMENT

The same holds true for the first two projects in the pipeline under the *Convergence* agreement: Orogen and Source-to-Sink. The first concerns the dynamics of mountain ranges, drawing on studies of the Pyrenees, broadly speaking since they include the continental margins of the Bay of Biscay to the west and the western Mediterranean basin to the east. The entire Pyrenees range, from the Golfe du Lion to the Cantabrian Cordillera in Spain, will be surveyed to investigate new scientific hypotheses and establish what might be called the "DNA" of mountain ranges. The second project focuses on the erosion processes that form sedimentary basins. Studies of the chronology and geographical distribution of erosion, sediment transport and deposit will verify their geological history and thus their petroleum potential.

How is your joint research being organised?

The *Convergence* agreement provides for close cooperation from the workplace. For the two projects, 45 researchers altogether will be working at Total and the BRGM (and at INSU for the Orogen project). Even if the project teams are not physically working together, the studies are integrated and undertaken in cooperation. The Total and BRGM project managers co-supervise the work, with the backing of a technical committee and guidance from a steering committee. Total is also calling on the BRGM for continuing training. All in all, *Convergence* is a very ambitious agreement since it represents 19 M€ in over five years (70% from Total and 30% from the BRGM).

A positive financial result and excellent prospects for the Carnot 3 label award

The BRGM, which received the Carnot Institute label in 2006, is nearing the term of the second labelling period. With its strong focus on building research partnerships, the strategy in the last five years has produced good results - and a new aim: to renew the Carnot label.

The BRGM Carnot Institute received the Carnot label when the scheme was first launched. This placed the BRGM within an overall framework for French research that aims to *"promote transfers of knowledge and technology, partnerships between public laboratories and businesses and innovative developments, in particular to engage in more effective cooperation with businesses, including major groups and especially SMEs"*.

In this context, the topic areas taken up by the BRGM Carnot Institute are highly relevant to issues of major concern to society that are directly related to the Paris Climate Agreement adopted under COP21 and to the French Energy Transition Act. These topics are addressed through four key themes: subsoil resources and uses, risk prevention, environmental precaution and development, and distribution of environmental data products. This is the foundation for the BRGM's unique scientific position among Carnot Institutes and the effectiveness of its activities since its previous application for the Carnot label in 2011.

Reinforcing the BRGM's thematic position to meet socio-economic needs

To give a brief outline of our work in the last five years, the BRGM Carnot Institute first organised its activities to match its thematic position to socio-economic demand, by implementing a strongly user-targeted policy. Long-term R&D partnerships covering all four themes were established with companies such as Total, Veolia, EDF, the CCR and ATOS. A multi-annual investment plan was launched to develop technological demonstrator platforms designed to resolve scientific issues raised by industrial partners and to strengthen their processes while meeting operational requirements.

Collaborative research and a significant capacity for involving businesses

Thanks to our policy for research partnerships, we have significantly increased our capacity for involving businesses, although more efforts will be needed in the coming years to attract SMEs and middle-market companies. This is being reinforced by our collaborative research approach at the national and European level, which is set to become a major asset for the BRGM Carnot Institute. In practice, this is an approach designed to open up to academic players (through contracts with the CNRS and universities and involvement in the governance of research alliances such as AllEnvi and ANCRE). The same approach holds for socio-economic players, through our involvement in governance and on the strategy committees of competitiveness clusters. Our strategy is also reflected in courses on research partnerships and meetings between researchers and SMEs, micro-enterprises and middle-market companies. Finally, our proactive policy to add value to research results through patenting, launched in 2013, has significantly increased the number of patent applications, with 20 claims filed in just 3 years.

"Thanks to the BRGM Carnot Institute's policy for research partnerships, we have significantly increased our capacity for involving businesses, although more efforts will be needed in the coming years to attract SMEs and middle-market companies."

Marie-Christine DICTOR
Programme Coordinator and Operations Manager,
BRGM Carnot Institute

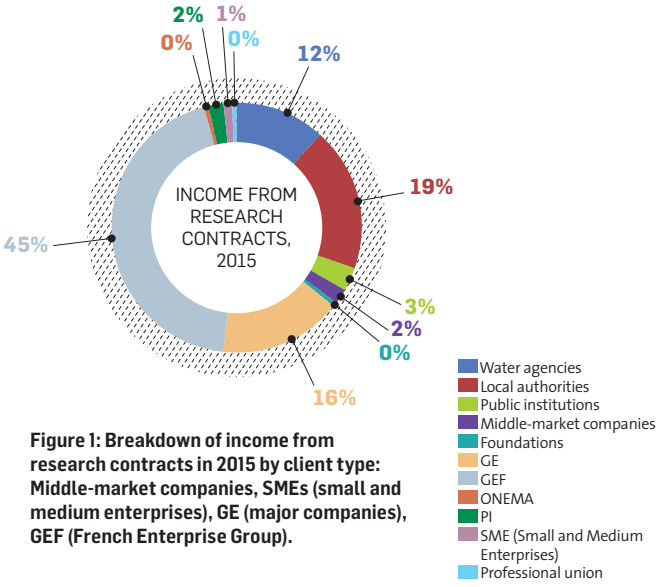


Figure 1: Breakdown of income from research contracts in 2015 by client type: Middle-market companies, SMEs (small and medium enterprises), GE (major companies), GEF (French Enterprise Group).

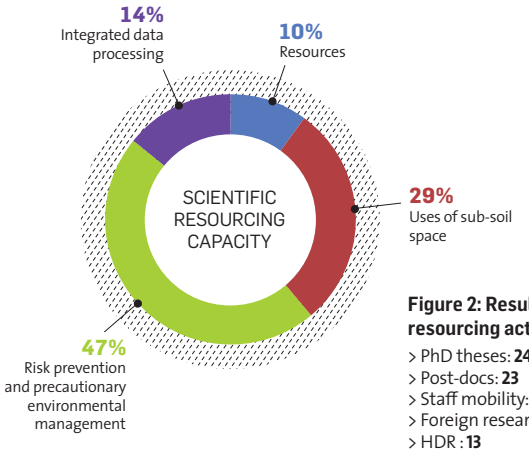


Figure 2: Results for resourcing activities

> PhD theses: **24**
> Post-docs: **23**
> Staff mobility: **19**
> Foreign researchers hosted: **7**
> HDR : **13**
> Investment projects: **7**

Close BRGM involvement in the Carnot Institutes network

The BRGM Carnot Institute has invested significant efforts in the Carnot Institutes network by taking an active part in seminars and the Carnot Meetings and by setting up strategic scientific cooperation agreements with other Carnot Institutes (ICEEL, IFREMER Edrome, IRSTEA, INRIA, ISIFOR, M.I.N.E.S). Three projects, which are supported by the Investing for the Future scheme, are conducted jointly with other Carnot Institutes: Captiven, Géodénergies and Labex Resources 21. In further projects selected in 2015, following a call for projects to develop organisational strategies to meet economic needs in SMEs and middle-market companies, the BRGM Carnot Institute is partnering EXTRA&CO for extractive and first-stage processing industries, and ENERGIC'S for the renewable energy and energy efficiency sector.

Tangible results

In 2015, collaborative research under contracts with socio-economic players, amounting to 6.4 M€, was mainly conducted through partnerships with major French and foreign companies. Income from contracts with SMEs dropped sharply during the 2010-2014 Carnot label period. This was due to the small number of small and medium companies working in the same sectors as the BRGM Carnot BRGM Institute. However, among the 42 collaborative projects supported by the ANR, 22 micro-enterprises and SMEs were partners in BRGM Carnot Institute projects, mainly in the areas of risk prevention and environmental precaution *(figure 1)*.

Our very positive results for scientific resourcing activities, shown in *figure 2*, reflect a high capacity in this area.

THE BRGM'S APPLICATION FOR A 3RD CARNOT LABEL IS BASED ON PAST RESULTS AND EXCELLENT PROSPECTS

The BRGM's two main strengths are its thematic positioning and international relations, in which we play a driving role through the Carnot network. Prospects are good despite the fact that the thematic perimeter will not change in the next three years: subsoil resources, risk prevention, precautionary environmental management and data product development.
The BRGM is a key player in the economic development of the Centre-Val-de-Loire region, and is also well established throughout mainland and overseas France thanks to its regional divisions. Our capacities for setting up projects backed by technological platforms have been clearly demonstrated.
A further asset is our key role in European networks and infrastructure. Thanks to long-term R&D partnerships with major groups, the BRGM has already achieved a high proportion of bilateral research contracts, with a view to the 2018 target of 20% of its consolidated research budget to be covered by such contracts. The BRGM is therefore poised for further development as a member of the Carnot network, which is contributing to the advancement of our research culture, strengthening our understanding of research needs in businesses and helping us to identify new sectors.

Karim Ben SLIMANE
Director, Development Division

Energy transition: the BRGM has strengthened its position at the hub of the circular economy and uses of the subsoil

The BRGM is directly involved in the energy transition.
We have strengthened our position at the hub of the circular economy, in line with the Energy Transition Act of 17 August 2015.

The BRGM is directly involved in many topic areas that are relevant to the energy transition, green growth and the circular economy. This position predates the new legal provisions under the French Energy Transition Act of 17 August 2015 (n° 2015-992), since the BRGM was already moving in this direction, for example as a founder member of the AllEnvi research alliance, an approach that was strengthened in 2015 by COP21 and which is also entirely in line with the new priority goals set out in the Energy Transition Act.

Research and innovation are key to the energy transition policy

The Act, which sets out the overarching goal of establishing "a new energy model in France", seeks to promote "green growth" by lowering the cost of energy in France and promoting new, clean and safe sources of energy. It also includes provisions to promote the circular economy and better waste management. The BRGM is a major player with a duty to contribute to research and innovation as keys to the success of the energy transition policy. Research and innovation are essential to meet the challenges we face.

> CCS technologies

The BRGM is working on concrete responses to several sections in the Act. Section 1 aims to "*define common goals to achieve a successful energy transition, strengthen France's energy independence and economic competitiveness, protect the health of people and the environment and fight climate change*". This directly concerns the BRGM, which is closely involved in developing Carbon Capture and Storage technologies (CCS) that could - despite the currently low market prices for CO_2 - contribute to the ultimate COP21 goal of reducing greenhouse gas emissions by 40% by 2030.

> Geothermal energy

Section 2 of the Act concerns the renovation of buildings to save energy and reduce energy costs, while Section 5 promotes renewable energy. Here again, the BRGM is in the front line, specifically as regards geothermal energy, which has significant potential for generating value from France's resources given that geothermal energy needs to be maintained as part of the energy mix. The BRGM is involved in research on very low-temperature geothermal applications, as well as in more "upstream" research in the high-temperature field. Examples include plans to develop advanced modelling approaches to improve predictions of the performance of deep geothermal systems (lifetime and yields) using scale models equipped with measuring instruments.

> Recycling and the circular economy

Section 4 also relates to the BRGM's core missions. This is aimed at "*preventing waste and promoting the circular economy, from product design to recycling*". The implications here are considerable, since the Act requires the government to submit to Parliament, every five years, "*a national strategy for the transition to a circular economy, including plans (...) to identify potential for preventing the use of primary and secondary raw materials in order to make more efficient use of resources, including strategic resources (...)*".

Regarding the circular economy, the BRGM therefore needs to pursue its development of innovative systems to recover critical metals from mine spoil and electronic waste, but also its studies to assess the availability of primary resources that are still essential at present. Studies

Under the Carboscories project, the BRGM and its partners conducted laboratory tests to finalise a new process for storing CO_2 in nickel production waste. © BRGM

on the management of final waste are also needed, with close attention to local contexts - again one of the BRGM's specific areas of competence. Regarding the use of subsoil space to promote renewables, the BRGM is again in the front line in the field of underground heat and energy storage, using hydrogen for example. Investments in research are especially crucial here.

Water stress is another of these key topics: in situations when water scarcity can become a factor limiting human activities and conventional approaches no longer suffice, water system managers can turn to alternative solutions such as the reuse of treated wastewater. Here again, the BRGM is working, in partnership, on solutions for energy production or irrigation. Developing innovative processes for reusing treated wastewater is one of the avenues to be explored.

> Information

Finally, Section 8 of the Act concerns consultations with civil society, aiming to "*confer on citizens, businesses and the State the power to move forward together*". It should be remembered that the BRGM, by virtue of its status as the French national geological survey organisation, is responsible for collecting, directly or from other sources, archiving and delivering information on all French subsoils in appropriate formats.

"The BRGM has put forward plans for activities that will support the energy transition: research and innovation make essential contributions to meet the challenges we face."

Pierre TOULHOAT
Deputy Managing Director and
Head of the Scientific Division

The BRGM has cut its GHG emissions by 45% in three years

Very positive results from the 2014 GHG emissions report, a new 5-year plan for renovating capital infrastructure in our laboratories, an energy audit, plans for waste treatment and paper consumption and ... sheep to graze our green areas: 2015 saw yet more activity in our drive to strengthen sustainability at the BRGM.

2015 saw a drive to further strengthen the BRGM's corporate social responsibility policy. The creation of the Central Secretariat on 1 September, a milestone in the overhaul of BRGM governance, was an opportunity to apply cross-cutting, synergy-based principles to position our CSR approach at the point of intersection between operational teams and support functions.

This has helped to consolidate and further develop the internal benefits of the CSR approach, through continued energy-saving, waste reduction and building management policies as well as through awareness-raising activities among our staff focusing on emission reductions in particular, with very positive results. Our purchasing policy is based on environmental compatibility criteria, which we also expect our suppliers to adhere to.

The BRGM's commitment to eco-responsibility and the environment is not a recent development. It has strengthened from year to year, with the BRGM's adoption of the Sustainability Charter in public institutions in 2008 and our ISO 14001 certification for "environmental management systems" in 2012 covering all of our research, advisory, expert and project management activities, which we were the first public industrial and commercial establishment (EPIC) to obtain.

This commitment reflects a strong culture of sustainability and environmental responsibility in our organisation. Our CSR activities in 2015 were deployed under a programme developed to put all BRGM activities and premises on a low-energy and sustainable footing in the medium term.

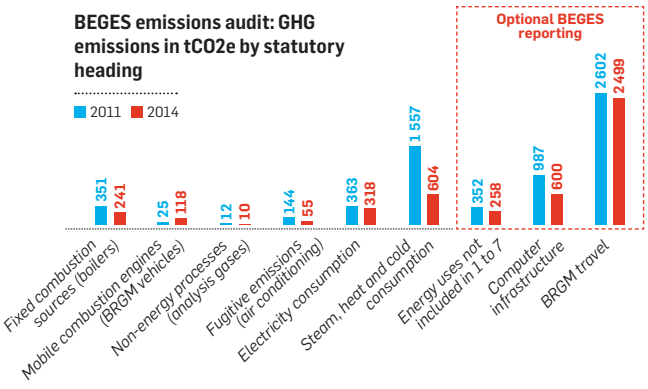
"Emission reductions are ahead of the targets set in the 2011 statutory emissions assessment."

Raymond GRENIER
Head of the working environment and sustainability department

Greenhouse gases: environmental impact significantly reduced

In 2015, the BRGM conducted its emissions audit (BEGES) for the year 2014. The audit covers three highly representative areas for which emissions were measured: direct emissions from fossil fuel burning (heating and vehicle fuel), direct fugitive emissions (air conditioning) and non-energy emissions (gases for laboratory use); indirect emissions from electricity and steam production (urban heating network) used by the BRGM; and finally, emissions from computer infrastructure and business travel, the latter being optional in BEGES audits but taken into account by the BRGM.

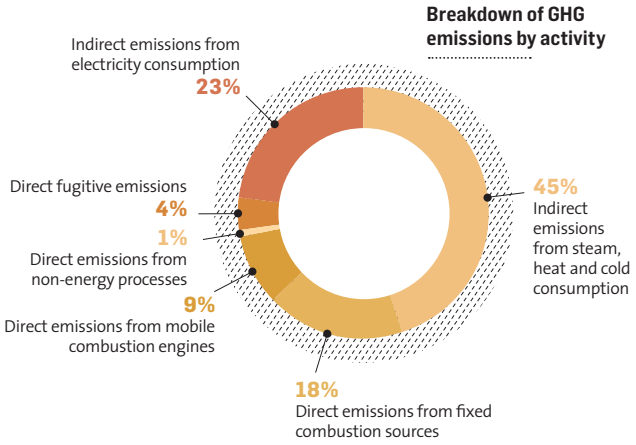
The results are spectacular. From 2011 to 2014, the BRGM's emissions dropped by 45% thanks to the efforts made throughout our organisation - way ahead of the 34% target set for statutory GHG audits in 2011. This equates to a reduction of 1123 tonnes of CO_2 equivalent in three



The results for 2014 show a 45% drop in emissions since 2011.

-3%

TARGET FOR ANNUAL EMISSION REDUCTIONS IN LINE WITH NATIONAL TARGETS



years, with emissions cut from 2 469 tCO2e to 1 346 tCO2e. This excellent result is largely due to the switch to biomass fuel for the SOCOS district heating network (-971 tCO2). However, the drop in electricity consumption, the removal of an oil-fired boiler in the PACA agency, the drop in gas consumption for scientific analyses and the replacement of cooling fluid in some air conditioning units also contributed.

A new action plan is in the pipeline for 2016-2018 to achieve emission reductions approaching the national target of around 3% per year, which would equate to a drop of about 40 tCO2e/year at the BRGM. The main activities will be to pursue the deployment of videoconferencing, provide training in eco-responsible driving, replace high-emission cooling fluids and continue to replace light bulbs, improve roof and terrace insulation and replace boilers.

Results from the 2015 energy audit are now being analysed, but it is already clear from the indicators in the State-BRGM performance contract *(see page 94)* that energy consumption is dropping significantly, with a 11.2% reduction since 2011 - already ahead of the -10% target set out in the contract for 2017.

Renovation of capital infrastructure in the BRGM's laboratories

Several laboratory infrastructure projects, designed with a view to energy saving and emission reductions, are included in the 5-year investment plan presented to the Board of Directors in October 2015. The plan includes renovation of the G1 building, which is already under way, rehabilitation of the G2 experimental facility with a view to hosting platforms for pilot projects supported by local authorities (such as the PIVOTS project) and, at a later stage, an entirely new laboratory building.

SHEEP TO KEEP THE GRASS DOWN

What might be the most efficient and eco-friendly way of maintaining the BRGM's green areas? The idea of using livestock was brought up in 2015 and went ahead in 2016, on a small parcel of BRGM land in Orléans, where sheep from the La Moutonte association are now keeping the grass down. This is not only an efficient way of maintaining natural areas - it could also be an original way of lifting people's spirits at work!

WASTE AND PAPER CONSUMPTION: DROPPING FAST!

Our 2015 results for waste treatment and paper consumption are very satisfactory indeed. The indicators in the State-BRGM performance contract *(see page 94)* show a 17.9% drop in paper consumption since 2012, well ahead of the -12% target for 2017. The number of photocopies in departments has dropped by 22.8% and by 29.6% at central reprographics.

2015 - a year of reorganisation

Human Resources in 2015 saw a major organisational change with the redefinition of the reference framework for its activities and the reorganisation, as of September, of its roles and activities into units.

1035

PEOPLE WORKING AT THE BRGM (31/12/2015)*

** Including 8 post-doc researchers, 13 Ph.D. candidates, 5 government-aided contracts, 8 VSC (civic service volunteers), 1 VIE (international enterprise volunteer) and 33 block-release interns.*

The main purpose of the reorganisation was to forge closer links between internal activities and those supporting management in the Divisions: recruitment and career management, training, administrative management, wages and workforce guidance. New staff were recruited to the department, with coaching to assist them in their tasks. These changes reflect a governance policy that clearly dedicates the human resources department to the service of our organisation and to the needs of its managers and employees.

The aim is for the our department, from its new position within the central secretariat established on 1 September 2015, to build capacities for providing advice and support to current and future projects.

Quality of life in the workplace

Under the "QVT" plan for quality of life in the workplace, the human resources department provided assistance to the "Management" component by developing a management chart to form the basis for a reference database on skills and competencies. Work was also undertaken to build capacities for psychosocial risk prevention and handling individual and collective situations. An alerting protocol was drawn up and introduced during the second semester via a brochure for managers and their teams.

Career management and forward skills and employment planning

On the career management front, an overhaul of recruitment procedures was launched, in line with the initial guidelines set out for forward skills and employment planning and supported by a draft framework agreement on these issues (signed in 2016).

Equality and diversity in the workplace

Finally, an agreement on equality in the workplace was signed in 2015, a specific post was created to assist people with disabilities and to promote diversity within the BRGM. Concerning the latter, an assessment was conducted in the last three months of the year as a basis for developing a 3-year action plan for 2016-2018.

Brochure on "Preventing distress at work". © BRGM

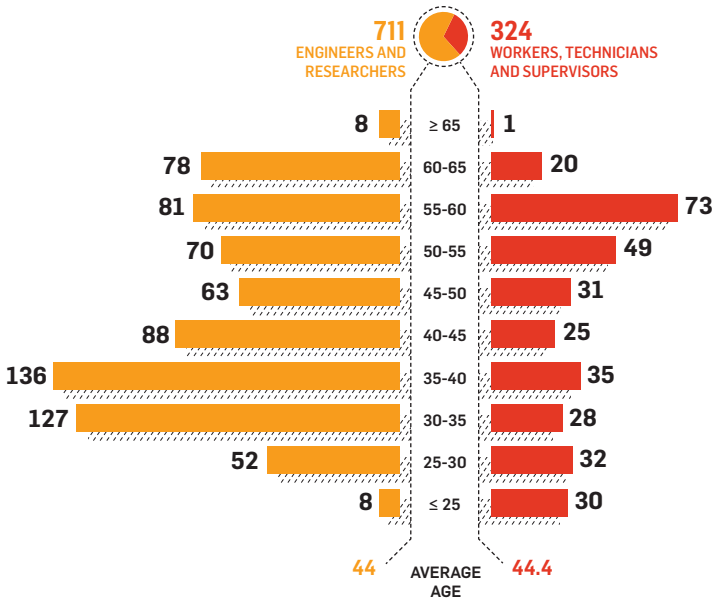
The BRGM Management Charter. © BRGM

"Providing advice and assistance for' current and future projects."

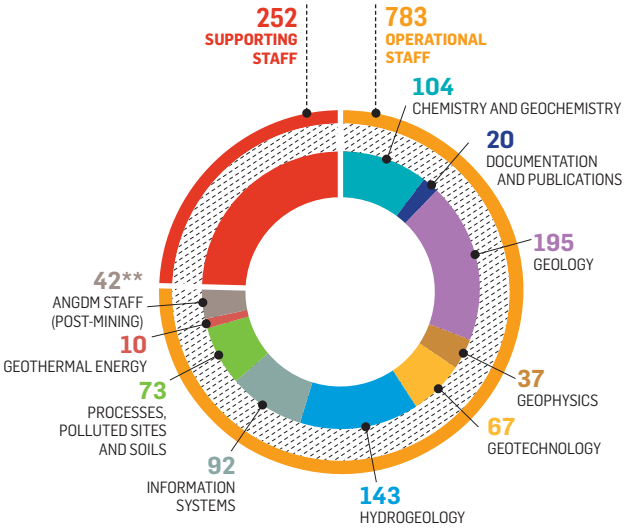
Claire GOVIN
Head of the Human Resources department

AGE PYRAMID BY CATEGORY

(31/12/2015)



BRGM STAFF BY PROFESSIONAL OCCUPATION



*** Staff made available to the BRGM for post-mining activities by the national miners' rights agency (ANGDM - Agence nationale pour la garantie des droits des mineurs).*

A CENTRAL SECRETARIAT TO TAKE DIRECT CHARGE OF CSR AND QUALITY OF LIFE IN THE WORKPLACE

To help meet priorities in the performance contract while improving quality of life at work, the BRGM established a Central Secretariat on 1 September 2015. Directed by Marie-Caroline Taillat, who is also in charge of human resources for the BRGM, the main function of the new central secretariat is to supervise and develop synergies between four departments and one unit: human resources, in-house and external communication and publications, legal support for procurement and contracts, the working environment, sustainability and health and safety. It also employs a manager for labour relations and dialogue in the workplace. The new central secretariat thus employs some 80 people altogether.

"*The synergies developed will help to boost the role of support staff in the work they do for the scientific activities conducted by the BRGM's six operational divisions*", explains Marie-Caroline Taillat, "*while reasserting the importance of the HR function and its links with in-house and workplace communication and clarifying the organisation of health and safety functions*".

The central secretariat also handles secretarial tasks for the careers committee, the staff review committee, the editorial committee and the committee for quality of life in the workplace; it contributes to the management committee, assists the Chairman in meetings with staff representatives and handles the secretariat for the BRGM board of directors. September to December 2015 saw the first consultative and coordination bodies set up between the different units in accordance with the new organisation chart, which became fully operational in January 2016.

Quality and Environment in 2015: successful renewal of ISO 14001 certification

In 2015, our ISO 9001 certification (quality management systems) was maintained while our ISO 14001 certification (environmental management systems) was renewed for another 3 years.

"Results are again positive" was the verdict following the external audits performed in late 2015 for ISO 9001 certification (first awarded in 2004) and ISO 14001 certification, which the BRGM was the first public industrial and commercial institution (EPIC) to obtain, in 2012. These conclusions confirm the relevance of our Quality and Environment management system, which is central to the day-to-day activities of all our managers and staff. They reflect the BRGM's concern for the satisfaction of its clients and partners and for keeping the environmental impacts of its activities to a minimum.

The certification audits were again conducted successfully at Orléans and in several regions (Corsica, Auvergne, Pays de Loire, Franche-Comté, UTAM Sud in Gardanne). Florence Auclaire, the BRGM's Quality and Environment delegate, is proud to say that *"no major problems were noted"*. Certification is essential because it provides a reference for the recognition of our work by our clients (private-sector service and industrial companies) and partners (supervisory ministries, local authorities, etc.). The procedures concern all our activities (research, advisory and expert services, project management) in all our topic areas: geology, water, geothermal energy, metrology, natural risks, mineral resources, post-mining, waste and polluted sites and information systems.

On the environment side, the activities undertaken have continued to reduce the volume of ordinary industrial waste (OIW) as well as paper and electricity consumption. Other reasons for satisfaction are customer appreciation, which has to be monitored under the ISO 9001 procedure and has remained very positive in 2015, while the response rate to the questionnaires, which rose again in 2015, reflects the interest of our clients in their partnerships with the BRGM. In 2015, 88% of our clients, said they were *"satisfied"* or *"very satisfied"* with the BRGM's products and services. The 12% of responses expressing less satisfaction concerned only three of the five criteria in the evaluation grid.

"A further endorsement for the BRGM's clients and partners of the quality of its scientific and technical work."

Florence AUCLAIRE
Quality and Environment Delegate

47%

OF DIRECT CLIENT RESPONSES TO OUR QUALITY ASSESSMENT SURVEY (41% IN 2013)

THE AUDIT DEPARTMENT: SUPPORTING BRGM GROUP PERFORMANCE

Identifying and managing risks and optimising processes are essential tasks for the Audit Department, to which the Quality and Environment Delegation is attached. With method, objectivity and independence as its watchwords, the Audit Department provides assistance, advice and recommendations to support BRGM and Group performance.

In 2015, the department broadened its scope of activity with audits of in-house risks and their management, and also of activities to assist managers and the managing director. A report submitted at the end of the year provided an in-depth review of the way the BRGM's activities in the field have evolved over the last 13 years. As head of department J. C. Perrussel explains, "*the work undertaken by our team, on the basis of HR data after their consolidation with operational managers, enabled us to establish a working typology of BRGM activities in the field, which had never been attempted before in this way and over such a long period*". Among the 7 types of activities, clear changes were identified in the maintenance of piezometric networks, drilling and core sampling, field geology and geophysics. The conclusions of the study were communicated to senior management level to support the development of strategic guidelines for the coming year.

The department also conducted an in-depth audit of the processes involved in missions and travel, which needed a review following the introduction of a new computerised system for mission management. The report identifies the main organisational and technical factors that need to be reviewed to improve the performance of the process.

The audit department again assisted the BRGM Group subsidiaries (with majority BRGM holdings) to review legal, financial and tax issues associated with mission expenses. "*This type of service is fully within the audits department's remit and ensures, through an overall and consistent approach, that Group governance is fully compliant with specific regulations*", says Jean-Christophe Perrussel.

As in the previous financial year, internal audits were also conducted as required by our ISO 9001 and 14001 certified Quality and Environmental management systems, synchronising the work with that of the Quality and Environment Delegation. Finally, the department works on risk mapping with the different Divisions, with a view to improving internal accounts and financial auditing. The results were presented to the Audit Committee and for information purposes to the Board of Directors, in accordance with the relevant Ministerial circulars.

Geologists surveying a weathering profile below a basalt formation in Saudi Arabia (Harrat Rahat, 2012). © BRGM - ALEXIS GUTIERREZ

"In 2015, we broadened our scope of intervention to operational topics, to support line management and senior management functions."

Jean-Christophe PERRUSSEL
Head of the Audit Department

Opening up the BRGM to civil society

In the context of the 2015 territorial reform in France, the BRGM pursued its activities to support public policy development in the regions, particularly on water and natural risks. Forging links between research and the needs of civil society is a new focus for the BRGM.

The 2015 territorial reform divided mainland France into thirteen large administrative regions, to which new competences was transferred for spatial planning, risks and water resources. As Stéphane Roy explains, *"until then, the BRGM's regional activities had been organised in accordance with the 22 existing administrative regions. For reasons of efficiency as well as consistency with the new administrative divisions, we decided to reorganise our regional agencies into thirteen divisions as from 1 January 2016."*

While the exact locations of the agencies in mainland France are still under discussion, institutional developments are being monitored to guide the decision-making process.

"How the transfer of new competences to the regional authorities will take place has yet to be clarified", says S. Roy. *"The BRGM's future remit as regards local and devolved government will depend on how the transfer of competences is implemented in each region."*

Water, risks and polluted soils

The BRGM's activities in the regions focused on two main areas in 2015, water resources and risks, with an increasing emphasis on environmental topics such as polluted sites and soils. As S. Roy explains, *"The coexistence of humans with the natural world has become a matter of major concern, as the recent COP21 discussions have made abundantly clear, and most of our regional activities are relevant to the issues that arise. An example is our work with the Seine-Normandy Water Agency on saline intrusions, which are contaminating drinking water resources in coastal areas. We have shown that excessive pumping is partly responsible for the problem, and have put forward solutions for better practices with less impact on the aquifer concerned."*

Coastal risks (flooding, erosion and receding coastlines, largely due to climate change) are another priority topic, which we are investigating in many coastal areas in Normandy, Picardy, Aquitaine and overseas France (Mayotte). Polluted soils, often a legacy of armed conflicts and an industrial past, are another area in which the BRGM's expert knowledge is in demand.

"With the Rhine-Meuse Water Agency, our teams have launched a major project in eastern France, in the WW1 'gas fields' near Verdun. More than a century after the Battle of Verdun, polluting substances, mainly from firearms and explosives, are still causing widespread soil and water contamination, and depollution in this context is a real scientific and technical challenge."

Close attention to concerns on the ground

"Whatever the issue, our role is to apply the fruits of the BRGM's research at the national level, and in turn to nourish that research with case studies in the regions. This means we often develop applied research projects, including inter-regional or transboundary projects as in the case of the "Pyrenees" study for the French Geological Reference Platform."

The BRGM's policy to adapt to issues on the ground in order to develop concrete responses to local needs is being strengthened: *"Through our work in the regions"*, explains S. Roy, *"where local authorities have always been our main contacts, the BRGM will now be opening up to a wide range of civil society organisations to give closer consideration to expectations from society. In 2015, we launched around a dozen pilot operations with NGOs and civil society groups to explain our operational role in applying research results while giving close attention to the concerns expressed by our fellow citizens. Building closer links between research and civil society by giving close attention to the needs expressed will help the BRGM to anticipate future needs and emerging concerns in the population."*

"Opening up to a wide range of civil society players to give closer consideration to needs expressed by the population."

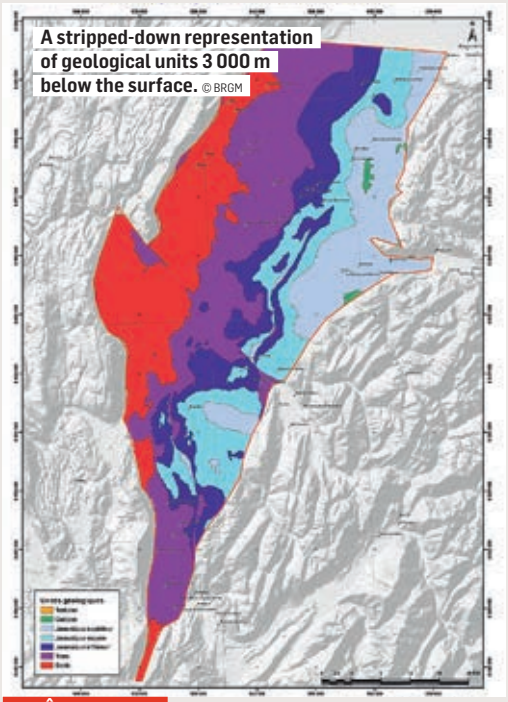
Stéphane ROY
Director, Regional Network

MAYOTTE

Curbing erosion and siltation in Mayotte's lagoon

The Leselam project for Mayotte's lagoon, now a UNESCO World Heritage site and an important factor of the island's development, is aiming to further understanding of the processes causing the erosion of its agricultural, urban and natural soils and to apply remedial measures (protecting slopes, conservation agriculture and soil restoration). Human pressure on this vulnerable environment is worsening the effects of erosion, which is becoming a threat to the lagoon due to massive sediment input. The aim of the project is to involve local players in joint activities to develop and apply technical and organisational measures designed to curb soil erosion, so that the quality of the lagoon environment can be sustained together with agricultural development and the rural habitat.
2015 saw the launch of continuous hydro-sedimentological monitoring of the Mtsamboro catchment basin, a highly urbanised 17-hectare coastal area, and the Dzoumogné basin (340 hectares of agricultural and natural areas with woodlands and padzas), the establishment of an analytical laboratory and the first information workshops with local farmers.

Measuring flows and sediments. © BRGM - BENARD



A stripped-down representation of geological units 3 000 m below the surface. © BRGM

RHÔNE-ALPES

Assessing natural resources in the region's pre-Alpine basins

The BRGM is participating in GeoMol, a new transboundary project to assess natural resources in the Rhône-Alpes region's pre-Alpine basins (geothermal energy and renewable energy, gas and CO2 storage). GeoMol, which involves 14 partners from Germany, Austria, France, Italy, Slovenia and Switzerland (geological survey organisations, academics, industries and government agencies) is developing a harmonised 3D geological model of the entire transboundary region. The project will deliver 3D information on the deep geological structure of the molasse basin stretching from France to Austria and of part of the Po valley, and assess certain types of geological potential in two pilot zones in the two basins. The surveys in the Savoy-Geneva pilot zone will produce a transnational assessment of geothermal potential in the Savoy-Geneva molasse basin, by building up a 3D model of deep underground temperature distribution, which will be linked to the 3D geological model and to the petrophysical parameters of the rock. The project results are available at www.geomol.eu.

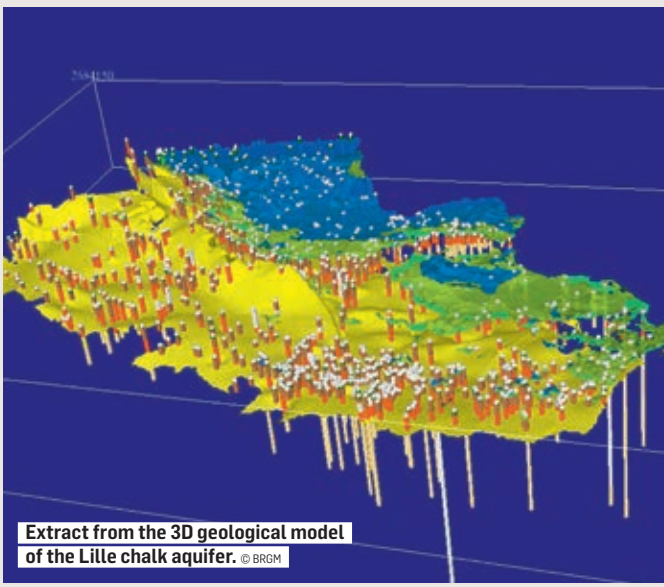
12

PILOT OPERATIONS TO HEAR CIVIL SOCIETY CONCERNS IN 2015

NORD-PAS-DE-CALAIS

Refining the hydrogeological model of the chalk aquifer

The chalk aquifer that covers some 60% of drinking water needs in the Lille urban area is also the most vulnerable to pollution. To address water quality problems and introduce a dynamic resource management system, Lille, one of the major European cities, commissioned a hydrodynamic modelling tool designed for the scale of the catchment basin. The model was built up from the regional model of the chalk aquifer (2013), reducing the size of the grid cells from 500 to 100 m in the catchment sector. Two surface layers were added to improve the representativeness of the flow model. The model, made up of 917 125 grid cells, was coupled with the carboniferous chalk model to give a better representation of the behaviour of the water table in the northern and central sectors of the urban area. The model was run in 2015 to provide data for analyses of the impacts of urban development projects on the future of the catchment areas to the south of Lille.



Extract from the 3D geological model of the Lille chalk aquifer. © BRGM

- ACQUISITION OF GEOLOGICAL AND GEOPHYSICAL DATA
- DIGITAL GEOLOGICAL MAPS
- SUBSOIL DATA PROCESSING
- FRENCH GEOLOGICAL REFERENCE PLATFORM
- GEOLOGY FOR SPATIAL PLANNING
- GEOLOGICAL MODELLING
- GEOLOGICAL APPLICATIONS FOR CO_2 STORAGE
- GEOLOGICAL INFORMATION SYSTEMS
- CARTOGRAPHIC COLLECTION

"The Pyrenees project has changed our understanding of the formation of mountain ranges."

GEOLOGY

3 QUESTIONS TO

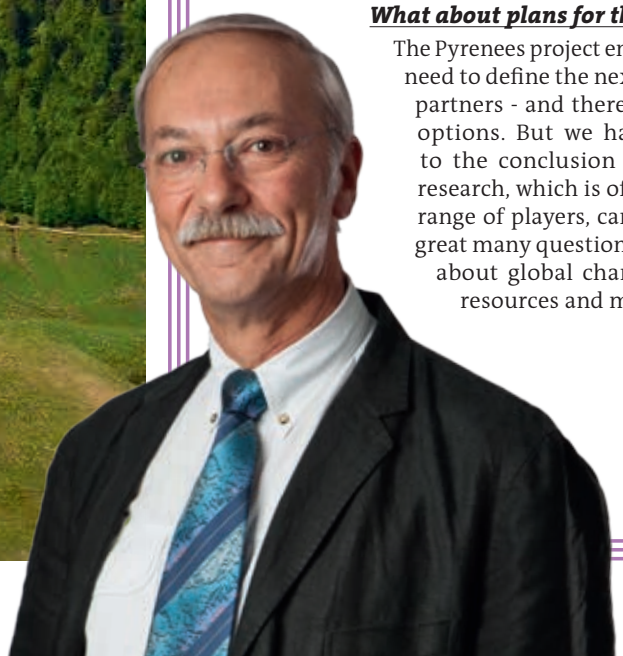
Didier BONIJOLY • Deputy Director of the Georesources Division

Can you tell us about progress with the French Geological Reference Platform and its first full-scale project on the Pyrenees?

The RGF is a project that our entire organisation is involved in. 60 years after the BRGM started work on the Geological Map of France, the aim now is to add to our knowledge of the subsoil, describe it accurately in 3D and make the data available to the scientific and economic communities and the general public. On the completion of a demonstrator model of eastern France, the Scientific Committee decided that the first full-scale RGF project would focus on a geological object that is little known despite its outstanding interest, and which the scientific community and the BRGM had already been researching through the ANR "Pyramid" project and the geological map of France programme: the Pyrenees.

Have any scientific advances been made?

There are a great many hypotheses on how the Pyrenees range was formed. Our studies are bringing us a new understanding of the creation of mountain reliefs. Based on our observations and map projections onto a flat surface, we now believe that during the Tertiary period, the relief of the Pyrenees would have been level with domed areas and that the relief today is the result of later events produced by a combination of collapse and climate change that disorganised the range and reactivated sediment flows. The importance of these findings has brought the BRGM, the CNRS and Total together to set up a joint research programme to resolve two important issues: understanding the factors that govern the way weathering occurs and how the rocks erode into sediment flowing into catchment basins, and identifying the parameters that govern temperature changes in these basins and in the organic matter that accumulates when they are involved in the formation of mountain ranges.



What about plans for the future?

The Pyrenees project ends in 2018. We now need to define the next project with our partners - and there are a great many options. But we have already come to the conclusion that this type of research, which is of interest to a wide range of players, can help to answer a great many questions from our society about global change, locating new resources and managing risks.

The Pic du Midi d'Ossau (Western Pyrenees). © YVANN K. FOTOLIA

HIGHLIGHTS

Predictive mapping of regolith lithology

The RegoCentre project, which draws on radiometric data acquired on the Centre-Val de Loire Region *via* the French Geological Reference Platform, has developed a methodology to produce predictive maps of regolith lithology in sedimentary contexts. The method involves combining airborne geophysics survey data with data on 5820 boreholes from the subsoils databank and information from about a hundred geodetic survey points. A demonstrator version has been produced for the regolith lithology map of the Loiret area.

A new airborne electromagnetic survey instrument ①

A new airborne electromagnetic survey system was jointly developed from the design to the data processing stage by the BRGM with a university laboratory and three SMEs. A prototype is shortly to be tested in real flight conditions.

Airborne demonstration campaign in New Caledonia ④

The BRGM and Denmark's Aarhus University (Ophiostruct project) completed an initial heliborne magnetic and electromagnetic survey in New Caledonia. Co-funded by CNRT-Nickel, the initial survey was conducted for demonstration purposes over several mining targets. Further surveys of additional targets were made, including for geological reconnaissance and to detect asbestos hazards for New Caledonia's Energy and Mines Department (DIMENC) and hydrogeological issues for the CGE-VKP (water management committee for the Voh-Kone-Pouembout zone).

Applications of geophysical survey results in overseas France

The knowledge infrastructure built up from the magnetism and electromagnetism data acquired by heliborne geophysical surveys in Mayotte, Martinique, Guadeloupe and La Reunion has proved to be invaluable to several dozen projects conducted to support the development of public or commercial policies. In 2015 in La Reunion, work has begun on a thesis on hydrogeophysics, while the Modpar project is using the data for its work on subsurface geometry and parameters at depths from 0 to 100m.

1/50 000 mapping programme ②

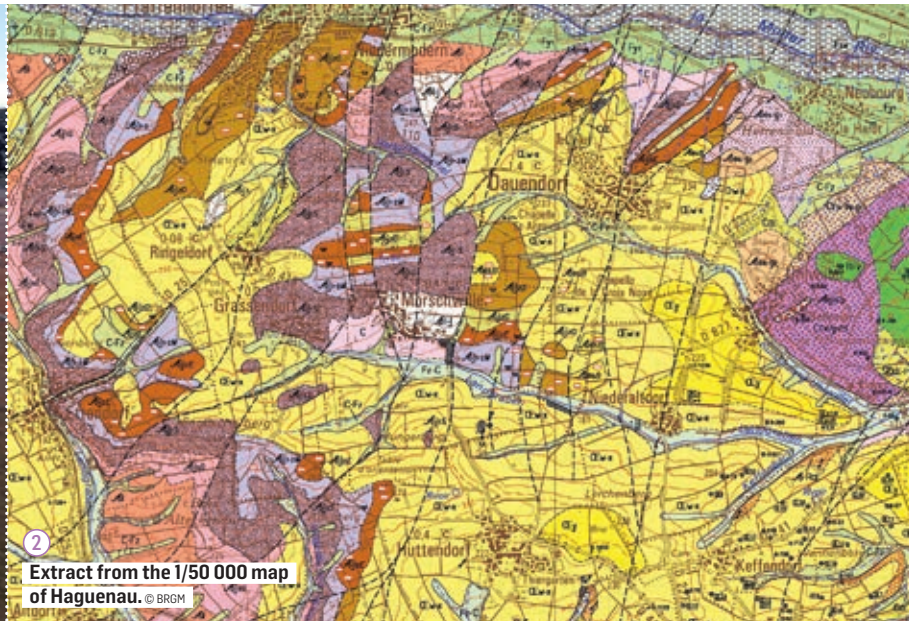
Several maps went on line in 2015, with their legends: Perros-Guirec, Haguenau (2nd ed.), Argeles-sur-Mer-Cerbere (1097) and Saint-Pierre et Miquelon. In production: Aubagne-Marseille (3rd ed.), Auray-Quiberon, Ile d'Yeu and Aspet. Print and on line publication of a map of surface formations to supplement the Haguenau sheet (Menillet 2015).

+ *http://geolfrance.brgm.fr*

Thickness of the Tertiary layer in France mapped for the first time ⑤

The map shows the total thickness of undifferentiated Tertiary deposits in France, in the form of a grid with 200m grid cells, with accompanying fault information including accidents that partly constrain the geometry of Cenozoic deposits. Additional studies will be made on other sectors where required.

① **Geophysical survey data from La Réunion are used to improve knowledge on the island's subsoils.** © BRGM



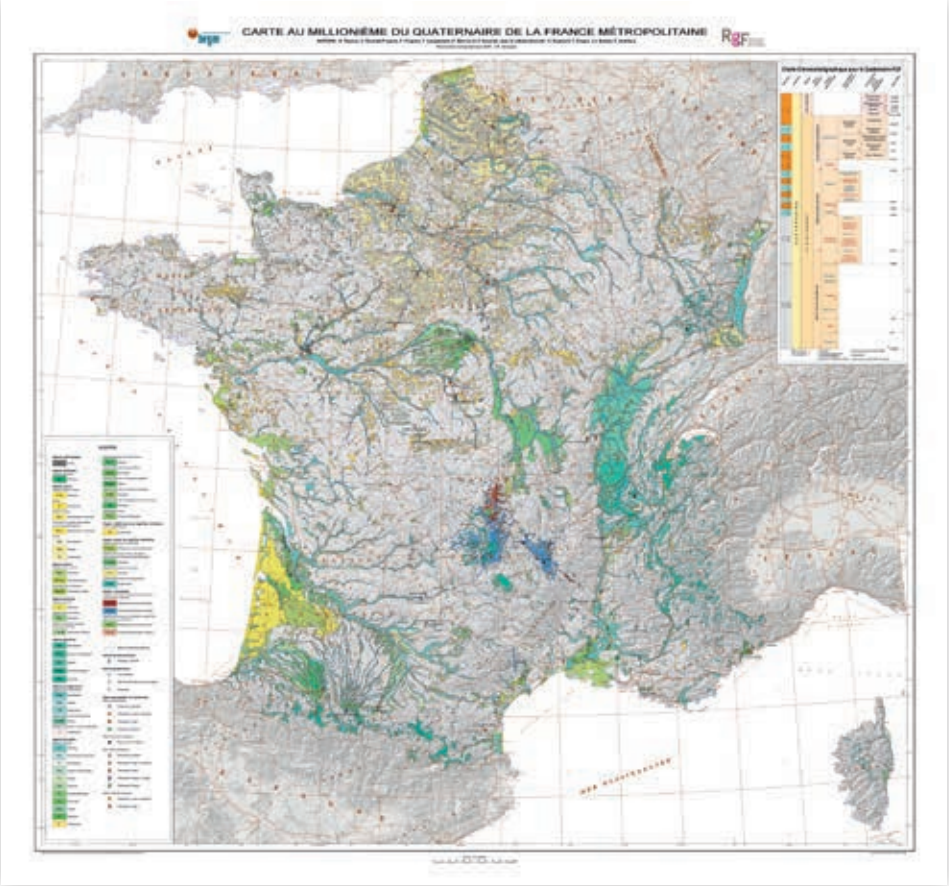
② **Extract from the 1/50 000 map of Haguenau.** © BRGM

1/1 000 000 MAP OF QUATERNARY FORMATIONS IN FRANCE

Quaternary formations cover a large part of France. Maps and data on the properties of these formations are in high demand for spatial planning and risk and resource management. Based on a review of current knowledge on regolith formations from 1/1 000 000 scale maps made in 2009 and from available thematic maps, this new map shows rock units with accompanying legends (e.g. sites of outstanding interest).

The 1/1 000 000 map of Quaternary geological formations in France.

© BRGM

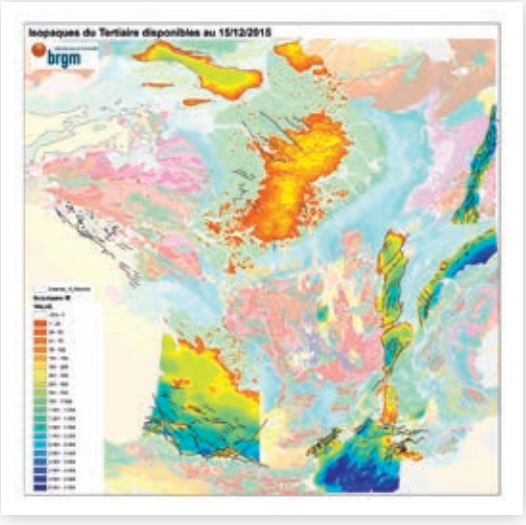


4 **A heliborne magnetic and electromagnetic survey in New Caledonia.**

© BRGM

5 **Map showing the depth of the Tertiary layer in France.**

© BRGM



"Convergence", a multiannual research partnership between the BRGM and Total

Thierry BAUDIN
Geologist, scientific manager for the RGF, "Orogen" project manager

Jean-Yves ROIG
Geologist, "Source to Sink" project manager

The BRGM and Total have signed an agreement on research to gain a new understanding of the geodynamic evolution of mountain ranges and its impact on the formation of hydrocarbons. Two projects, "*Orogen*" and "*Source to sink*", are focusing on the Pyrenees range, the subject of the first full-scale project for the French Geological Reference Platform.

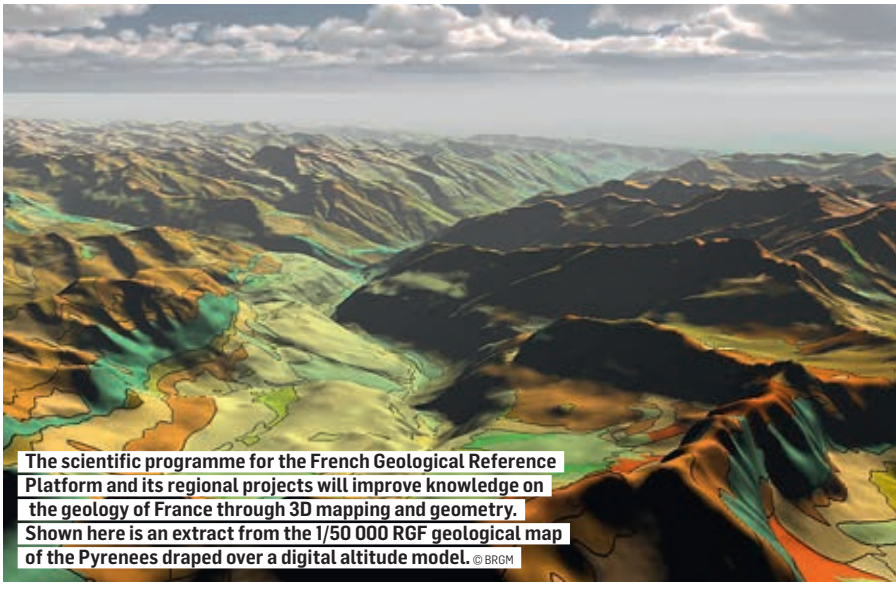
As longstanding partners, the BRGM and Total have just signed a new framework agreement called "Convergence" (2015-2020), which will employ about a dozen full-time researchers. The aim is to develop new approaches to understand the formation and evolution of mountain ranges in collision zones and to reconsider the processes involved in the distribution and transformation of organic matter from which hydrocarbons were formed and in the formation and location of the reservoirs in which they are found.

Orogen: identifying the "DNA" of mountain ranges

"*Orogen*", explains Thierry Baudin, the scientific manager of the RGF programme, "*is a holistic project that aims to understand the nature of mountain ranges and the fundamental parameters that govern their formation and evolution. The idea is to identify the "DNA", so to speak, of orogens. The Pyrenees are of particular interest in this respect. They are an anomaly among the world's mountain ranges, because they exhibit an entire orogenic cycle, from the original exhumation of mantle rock with rupturing of the continental plate to the first convergence movement, and through to the destruction of the range with the breakaway of the Corsica-Sardinia block followed by closure of the basin.*"

The researchers will focus on understanding the impact of the deep geological organisation of mountain ranges on their tectono-sedimentary evolution. "*These studies*", explains T. Baudin, "*which will also*

"Through Convergence, the BRGM and Total are working in synergy on scientific and industrial issues"



The scientific programme for the French Geological Reference Platform and its regional projects will improve knowledge on the geology of France through 3D mapping and geometry. Shown here is an extract from the 1/50 000 RGF geological map of the Pyrenees draped over a digital altitude model. © BRGM

involve the INSU and universities, will draw on every kind of research conducted on the Pyrenees in the last hundred years and more, which will be collected and synthesised. Sixteen PhD candidates and eleven post-docs will be involved, working in some fifteen laboratories in France and elsewhere."*

"Source to sink": from hydrocarbon sources to storage

"*The Source-to-Sink project*", says geologist Jean-Yves Roig, "*includes a component focusing on the compressive Pyrenean context, which affects the entire west European coast. It aims to further knowledge on the processes involved in the creation and erosion of mountain reliefs and on the parameters that govern sediment deposits in downstream basins. The project will draw on observations, characterisation and dating of the weathered surfaces that mark the end of mechanical erosion of the relief, which will help to understand the evolution of sedimentary systems and to constrain modelling of the processes involved in the relief's destruction over time and space.*"

Another component will focus on French Guiana's passive margins, formed by sediment deposit in the ocean: "*we hope to get a clearer picture, on land, of the periods when mechanical erosion and chemical weathering (formation of lateritic surfaces) were taking place, which we will then correlate with the geometry and typology of marine deposits.*"

This is of obvious interest to both parties: a better understanding of these mechanisms will help Total to assess resource potential during explorations and to improve their management of the latter, while advances in the understanding of weathered surfaces and sedimentary systems are a promising prospect for the BRGM as they could produce numerous applications in the fields of mineral and hydrogeological resources, natural risks, spatial planning and geothermal energy production.

19 M€

THE "CONVERGENCE" BUDGET

Geologists on a field mission in the Pyrenees.

** National Sciences of the Universe Institute.*

MINERAL RESOURCE ECONOMICS
MINERAL DEPOSIT MODELLING
IDENTIFICATION OF RESOURCES AND RESERVES
EXPERT OPERATIONAL AND POST-MINING STUDIES
DEVELOPMENT STRATEGY
KNOWLEDGE TRANSFER

"We are working to support good governance in the mineral resources industry."

MINERAL RESOURCES

3 QUESTIONS TO

Jean-Claude GUILLANEAU • Director, Georesources Division

The BRGM is closely involved in programmes to support governance in mineral resource prospecting and extraction. What are the issues at stake here?

Mineral resources are a topic area in which numerous sociological, economic, environmental and industrial issues converge, and good governance of the sector is a major challenge for the countries concerned. The BRGM is increasingly called upon for its scientific as well as technical and strategic expertise in this area. Good governance of mineral resources with a view to the sector's sustainability relies on the observance of three complementary principles. First, knowledge of both existing or potential resources, and the ability to manage them; secondly, extraction must take place under optimum conditions, which includes action against illegal mining practice, and thirdly, organising and implementing specialised services and skills.

In what ways did the BRGM apply its expertise in France and Europe in 2015?

We took a very active part in the "Responsible Mining" project, which was officially launched in April 2015 with a charter for the resumption of mining in France. In parallel, we worked on a reassessment of targets listed in the mines inventory drawn up from 1975 to 1991, in order to produce new maps of French mineral resource potential. In Europe, the BRGM, which is specifically responsible for producing maps of mineral resources and potential in Europe, completed the 2013-2015 Minerals4EU project with its partners, the aim of which was to set up an online information platform on mineral resources in Europe.

And in other countries?

We launched a major project to support governance in the Democratic Republic of the Congo, which commissioned us to design its new geological survey organisation. Also in Africa, we handled the set-up and coordination for the EU of the 3-year PanAf-Geo project to train over 1 000 professionals working for geological surveys in the 54 countries of the African continent. This exceptionally large and ambitious project will involve 12 European geological survey organisations working closely with EuroGeoSurveys and the OAGS, the umbrella organisations for European and African geological surveys.

The Villeveyrac bauxite mine in southern France. © FRANÇOIS MICHEL

HIGHLIGHTS

Reassessment of mineral potential in France ②

From 2013 to 2015, on request from the State, the BRGM conducted a reassessment of identified mining targets in France. 98 files on targets of interest were reassessed on the basis of reprocessed geochemical data from the French Mines Inventory (1975-1991) and updated metallogenic and economic information. 95 technical files on potential mining targets are available, 7 of which are of particular interest: Beauvain (Mo), Courcelles-Fremoy (F, Ba), Egreuil (F, Ba), Fumade (W), Pierre-Perthuis (F, Ba), Salau (W) and Treguennec (Sn, Ta, Nb, Li, Be).

Two Ph.D. theses

These BRGM theses submitted in 2015 were co-financed by the Centre Region and the Voltaire Labex. The thesis by Armel Menant is entitled "From mantle to crust: subduction dynamics and mineralised systems in the eastern Mediterranean"; the other, by Sarah Deveaud, focuses on "characterisation of the deposit of pegmatite fields with rare elements of the LCT type: representative examples in the Varisque range".

Monograph on the tungsten district in the Montagne Noire range

A report on "promoting mining districts in mainland France: the tungsten district in the Montagne Noire range" (S France) has just been published. The favourability studies identified six sectors, three with high potential: the Lacaune Range and Montredon-Labessonnie dome, which were already known, and a new "north-eastern" zone identified by reprocessing geochemical data from the 1975-1991 mines inventory.

Criticality of rare earths for French industry

Since 2010, the BRGM has been producing monographs on strategic metals for the French economy for the COMES committee on strategic metals. An overview of the rare earths market, which reviews current knowledge on these metal elements and their markets, is now available. The criticality of these elements depends on their importance for a great many technological sectors (permanent magnets, lasers, low-energy light bulbs, etc.) and industries (aeronautics, electronics, telecommunications, renewable energy, etc.) as well as on their availability.

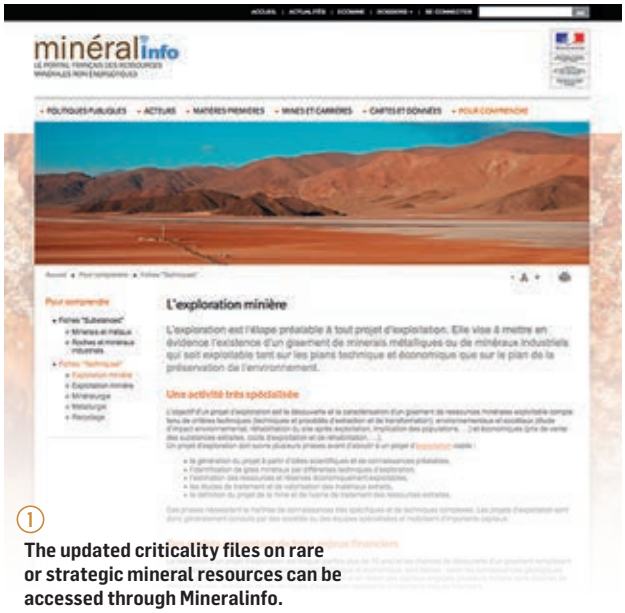
Updating the map of critical substances in Europe ③

In 2015, the BRGM updated its map of critical substances in Europe, adding data from a new list published by the EU. This map was one of the main deliverables of the ProMine project (2009-2012 programme under the 7th FPRD, aiming to diversify sources of strategic metal supplies to Europe) and contributed substantially to the success of the project, which earned the "best completed EU project" award.

Mineral criticality files ①

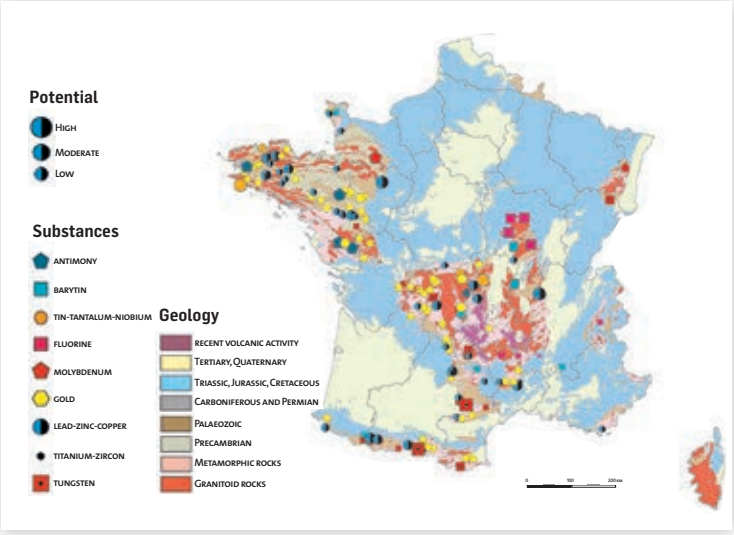
As part of its work on the criticality of rare or strategic mineral resources, the BRGM published eight updated "criticality status files" in 2015, on antimony, cobalt, germanium, neodyme, palladium, platinum, tantalum and tungsten. These files are available on line on Mineralinfo. The list will be extended in 2016, to include important industrial minerals such as copper, tin and aluminium in particular.

⊕ ***www.mineralinfo.fr***



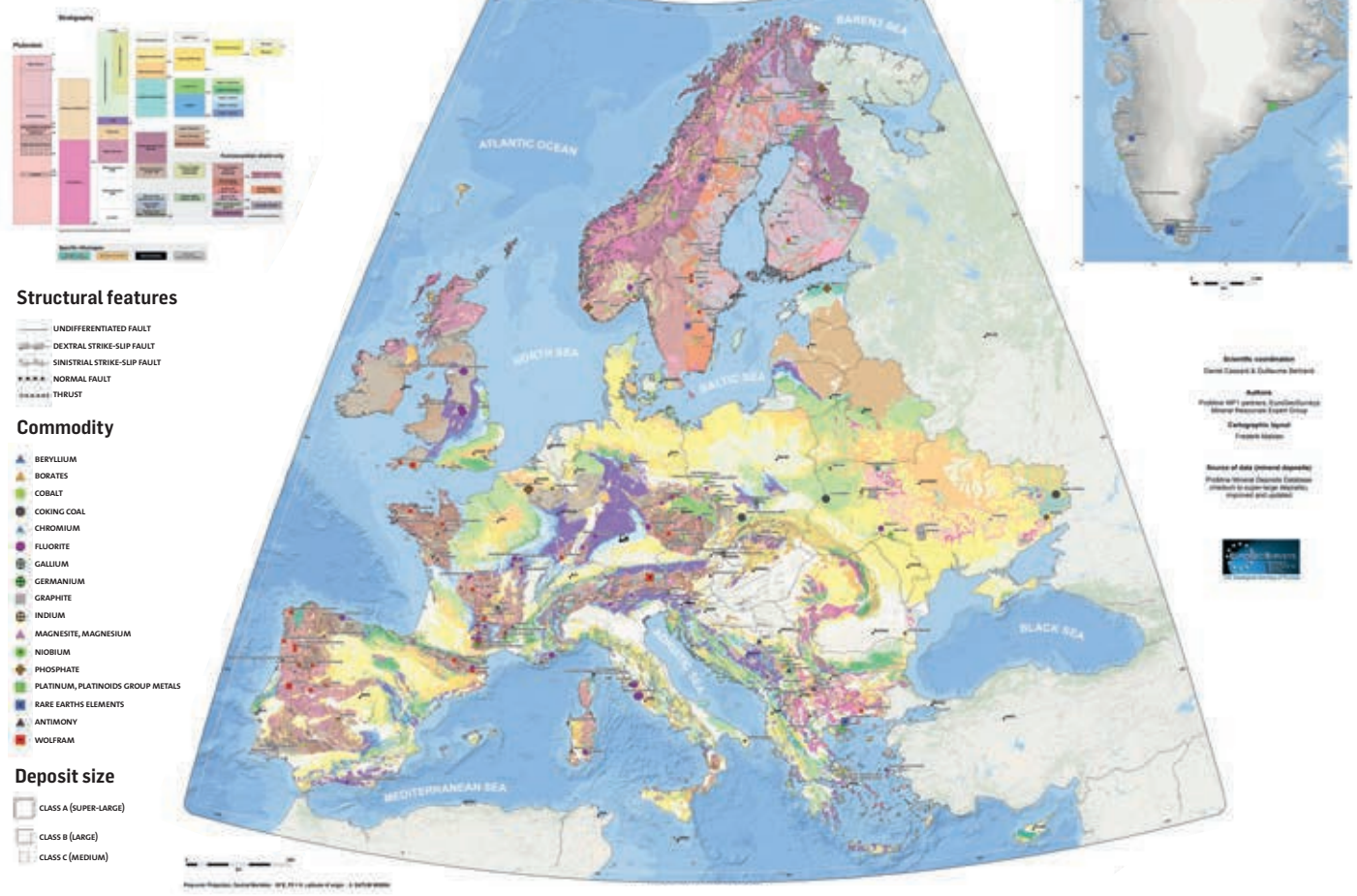
① **The updated criticality files on rare or strategic mineral resources can be accessed through Mineralinfo.**

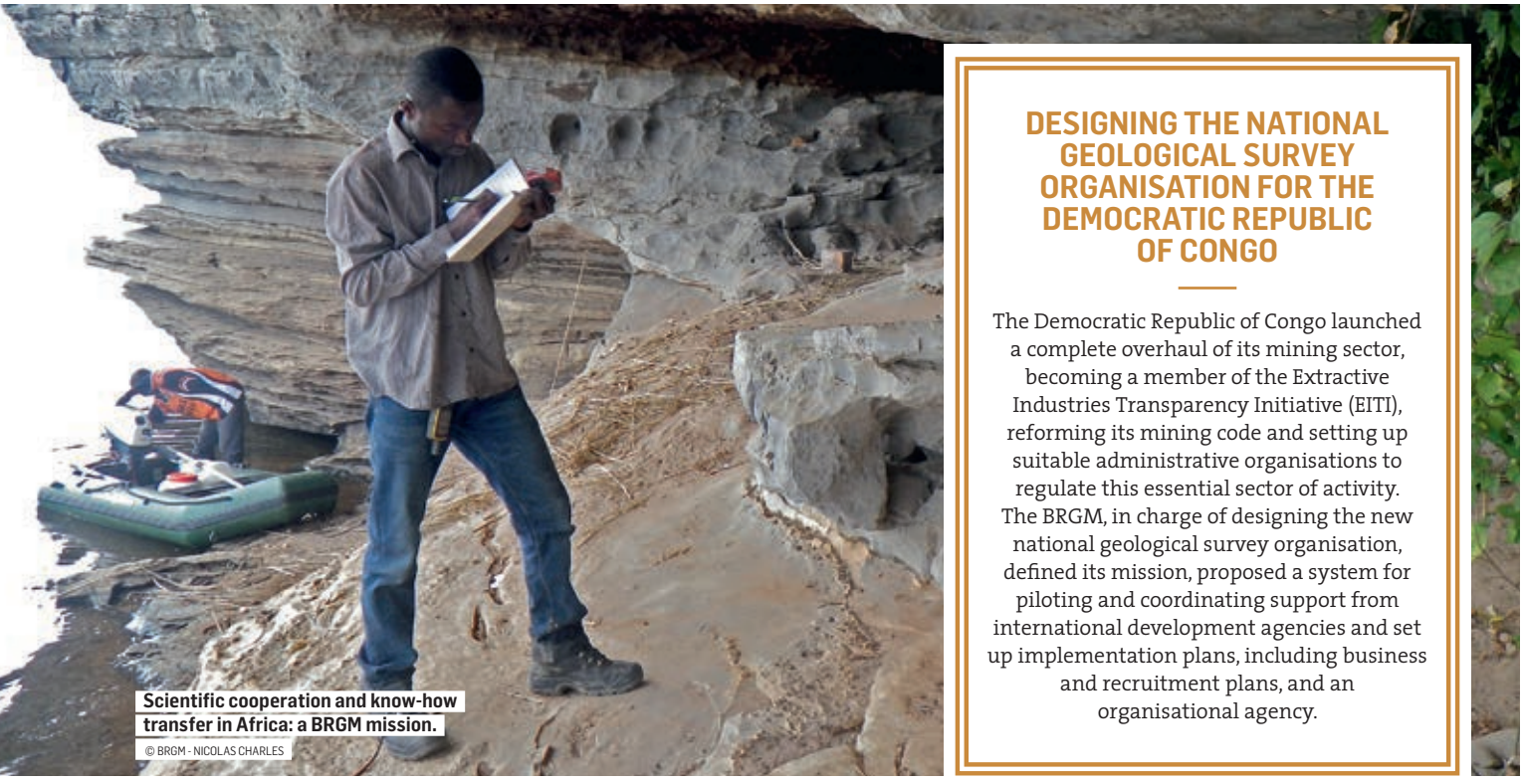
② **Map of mining potential in France.** © BRGM



③

Map of critical substances in Europe updated in 2015. © BRGM





Scientific cooperation and know-how transfer in Africa: a BRGM mission.

© BRGM - NICOLAS CHARLES

DESIGNING THE NATIONAL GEOLOGICAL SURVEY ORGANISATION FOR THE DEMOCRATIC REPUBLIC OF CONGO

The Democratic Republic of Congo launched a complete overhaul of its mining sector, becoming a member of the Extractive Industries Transparency Initiative (EITI), reforming its mining code and setting up suitable administrative organisations to regulate this essential sector of activity. The BRGM, in charge of designing the new national geological survey organisation, defined its mission, proposed a system for piloting and coordinating support from international development agencies and set up implementation plans, including business and recruitment plans, and an organisational agency.

Research worth gold dust in French Guiana

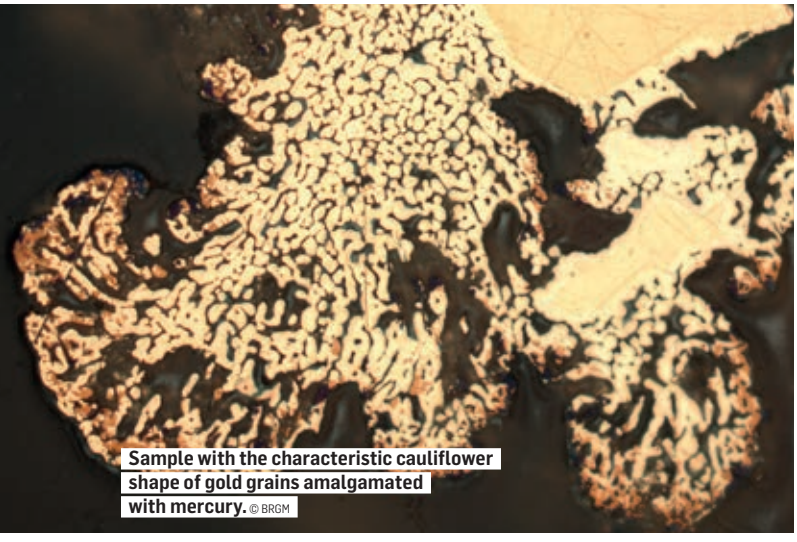
Laurent BAILLY
Project manager

To help fight illegal gold production in French Guiana, the BRGM has developed a method that produces a physicochemical "identity card" for each gold sample, so that its geographical provenance and method of production can be determined.

In French Guiana, illegal gold panning is having disastrous impacts on people and the environment. The method of production used by illegal panners involves a mercury-based amalgamation process, and is causing severe pollution in forests and rivers, while competition between some 10 000 "garimpeiros", many of whom are undocumented workers from neighbouring countries, frequently flares up into violence.

"*Illegal gold production in Guiana is estimated at about 10 tonnes a year, as compared to one to two tonnes of legal production*", says the BRGM's Laurent Bailly, who heads the European TAO project on analytical tracing of gold in Guiana, conducted with the WWF.

> ***"The cauliflower shape of gold nuggets that have been amalgamated with mercury is characteristic of illegal production"***



Sample with the characteristic cauliflower shape of gold grains amalgamated with mercury. © BRGM

But curbing these illegal activities, which involve hundreds of small production sites (204 identified in 2015 by the "Harpie" military operation against illegal gold panning), is not a simple matter.

"*The solution we decided to work on,*" says L. Bailly, "*involves tracing the gold coming onto the market to identify the method of production, but also its geographical origin, by investigating the mineralogical and chemical characteristics that are specific to each deposit.*"

Several complementary methods

The work undertaken in Guiana is the first of its kind. The research involved applying a series of physicochemical analysis techniques to 30 samples from seven known deposits in Guiana and 4 samples from neighbouring Suriname produced by mercury amalgamation.

As L. Bailly explains, "*we investigated the morphological and chemical characteristics of the*

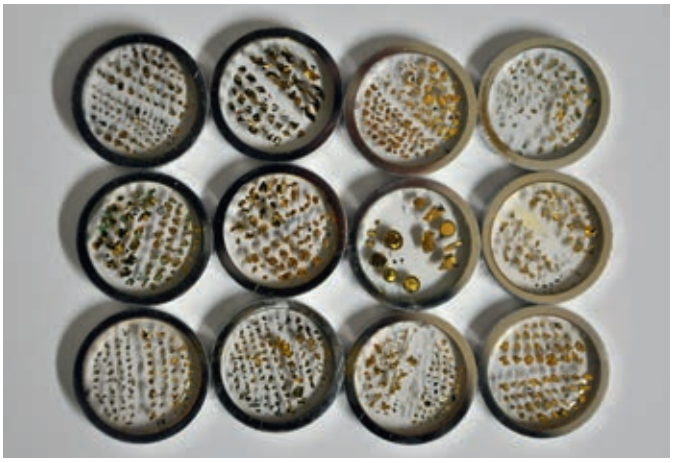
nuggets, using a series of methods from microscope observations of their shape, colour and any mineral inclusions to isotopic analyses, with each method providing different clues. These analyses enabled us to determine a physicochemical "identity card" for each sample, which gives the "signature" of the mining area they came from."

The method also produced a characterisation of the production method used, which is of major importance to fight illegal gold production.

"The shape of the grains is different depending on whether they are from primary or alluvial deposits or produced by amalgamation. Grains taken from close to their primary source have relatively flat surfaces on which the imprints of associated minerals can be seen. They become more rounded when carried away by a stream. When a mercury-based amalgamation process has been used, the chemical reaction produces a characteristically cauliflower-shaped deformation."

Work is still in the early stages and the methods need to be refined. However, the results so far are very promising and the next few years could see the creation of a reference databank in Guiana. This would make the legal situation more secure by ensuring full traceability of products coming onto the market, thus providing better guarantees as to their origin.

Analysing gold samples from French Guiana.
© BRGM



10 TONNES /YEAR

ESTIMATED QUANTITY OF GOLD PRODUCED EACH YEAR IN GUIANA BY UNDOCUMENTED WORKERS

Shape, colour and mineral inclusions in gold samples from Guiana seen under a microscope. A physicochemical "identity card" for each sample can be determined by combining different methods of analysis. © BRGM - PIERRE VASSAL

GEOTHERMAL HEATING VIA HEAT PUMPS FOR INDIVIDUAL AND COLLECTIVE HOUSING AND THE TERTIARY SECTOR

DIRECT USE OF GEOTHERMAL HEAT FOR HEATING NETWORKS

HIGH-TEMPERATURE GEOTHERMAL APPLICATIONS FOR ELECTRICITY PRODUCTION

ENHANCED GEOTHERMAL SYSTEMS (EGS)

"For the first time in France: an advisory unit for geothermal energy development in the regions."

GEOTHERMAL ENERGY

3 QUESTIONS TO

Philippe ROCHER • Deputy Director and Head of the Geothermal Energy department, Georesources Division

In 2015, what were the highlights in geothermal energy for the BRGM?

We were involved in several projects on minimum-impact geothermal energy: producing information on the new regulations, new mapping developments and delivering content on the new filing procedures for very low energy geothermal projects, which is now available on line from the renovated www.geothermie-perspectives site. Several French and European projects were launched on deep geothermal energy for electricity production or CHP and EGF technology. These projects, which are piloted by industries and involve several partners, including the BRGM, aim to set up demonstrators to promote geothermal energy across mainland France.

What about activities in the regions?

Under an emblematic and innovative policy, applied in partnership with the ADEME, the BRGM is appointing regional advisers on geothermal energy, with the Aquitaine agency leading the way. The aim is to help project developers and their engineering consultancies to assess the relevance of geothermal energy for heat supplies. The first significant results concern low-energy operations in urban areas (Bordeaux, Pau and Oloron-Sainte-Marie) and very low-energy operations in municipal, winegrowing and agricultural areas, where geothermal energy can supply both heating and cooling for production premises and processes.

In the volcanic contexts of overseas France, how are the projects for generating electricity progressing?

Besides opening up the capital of Géothermie Bouillante in Guadeloupe, the BRGM also completed the EU Interreg Caraïbes IV programme and took part in the Géothermie Caraïbe 2 closing seminar. The purpose of this programme was to establish favourable conditions for the emergence of electricity production projects in the Caribbean Arc. The BRGM developed tools to inform the population about high-energy geothermal applications in the Caribbean, distributing scientific and general public information (including brochures, four videos and other communication materials).

The drilling site for 67 vertical geothermal probes in the Pontet-Canet vineyard (Bordeaux region).

HIGHLIGHTS

Soultz-sous-Forêts: from scientific pilot to EGS demonstrators ①

2015 was a transitional year for the BRGM in its activities to support the development of scientific approaches to deep geothermal heat extraction using unconventional methods such as EGS (Enhanced Geothermal Systems). Building on the experience gained through assistance and studies at the scientific pilot at Soultz-sous-Forêts, the BRGM is now taking part in projects for future demonstrators (AMI FONGEOSEC and H2020 DEEP EGS), and also supporting industrial developments in mainland France under projects run by Geodenergies. These different projects will contribute to the development of an EGS (Enhanced Geothermal Systems) subsector in France and Europe by transferring scientific and technological knowledge to new industries, particularly through programmes under the Investing for the Future scheme. They will involve all of the EGS competences of BRGM teams (geology, geophysics, geochemistry and THM modelling) for the characterisation of geological targets and for analysing and modelling associated phenomena.

Gecko: Developing geothermal infrastructure ③

Gecko, an experimentation and modelling project conducted under an ANR partnership, aimed to define conditions for the manufacture and use of geothermal probes in order to promote their use in sustainable cities and buildings. The project drew on experience gained through the BRGM's geothermal platform, in particular on temperature measurements *via* a fibre optic network.

BRGM participation in geothermal insurance schemes

Two kinds of insurance schemes currently cover geothermal operations, one for short term risks (flow and/or temperature problems) and one for long-term risks (depletion of the resource or accidents). The Aquapac scheme covers very low-energy activities. In 2015, the committee (of which the BRGM is a member) investigated 23 cases. The second scheme, which was established in the 1980s with the development of geothermal heat extraction from the Dogger aquifer, was overhauled in 2006 to become a geothermal guarantee fund. The BRGM is regularly commissioned by SAF Environnement, which manages the fund, for expert studies of deep boreholes in the case of guarantee or insurance claims. From 2014 to 2015, the number of expert studies rose to 23, reflecting the large number of boreholes drilled from 2013 to 2015 (27).

Geothermal energy and wastewater ②

Under the EcoCities project (Investing for the Future), the BRGM made a study on energy independence combining very low-energy geothermal potential with reused wastewater in the Clermont-Ferrand urban area. The final project results were presented in early 2015.

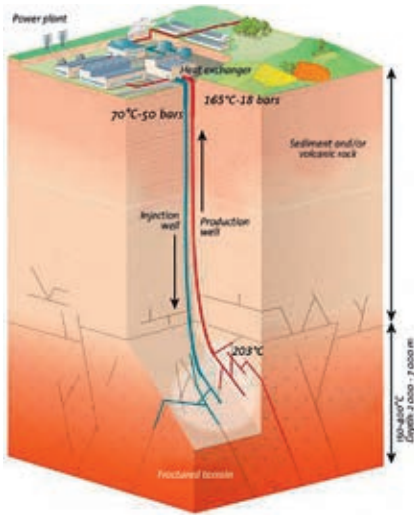
ReGeoCities, to help bring geothermal energy into wider use

The BRGM took part in the European ReGeoCities project aiming to help achieve the goals in the French national renewable energy plan, with a particular focus on shallow geothermal sources. The main aims were to address obstacles in the regulations, disseminate good practice, prepare a common basis for standards development and define a training framework for administrative players. The end result was a EU-wide information campaign.

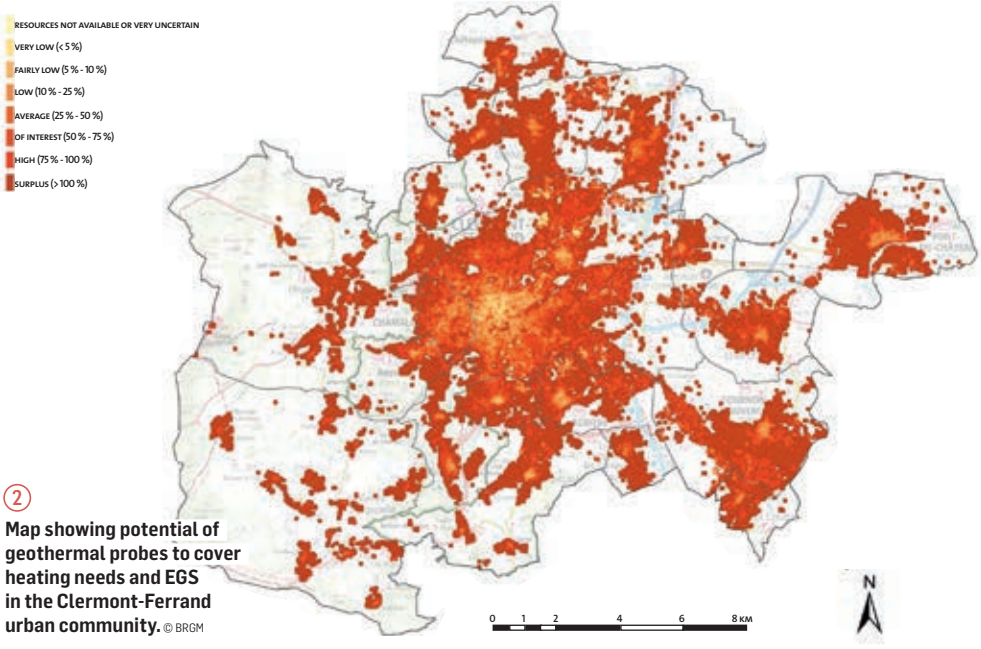
⊕ ***www.heatunderyourfeet.eu***

Geothermal developments in overseas France ④

The BRGM produced a report for the Ademe on boosting geothermal energy production in La Réunion and also took part in the closing seminar of the EU Interreg IV project, whose component on geothermal energy in the Caribbean aimed to develop high-enthalpy geothermal applications in the Caribbean Arc.



① **Operating principle of the EGS demonstrator at Soultz-sous-Forêts (NE France).** © BRGM



② **Map showing potential of geothermal probes to cover heating needs and EGS in the Clermont-Ferrand urban community.** © BRGM

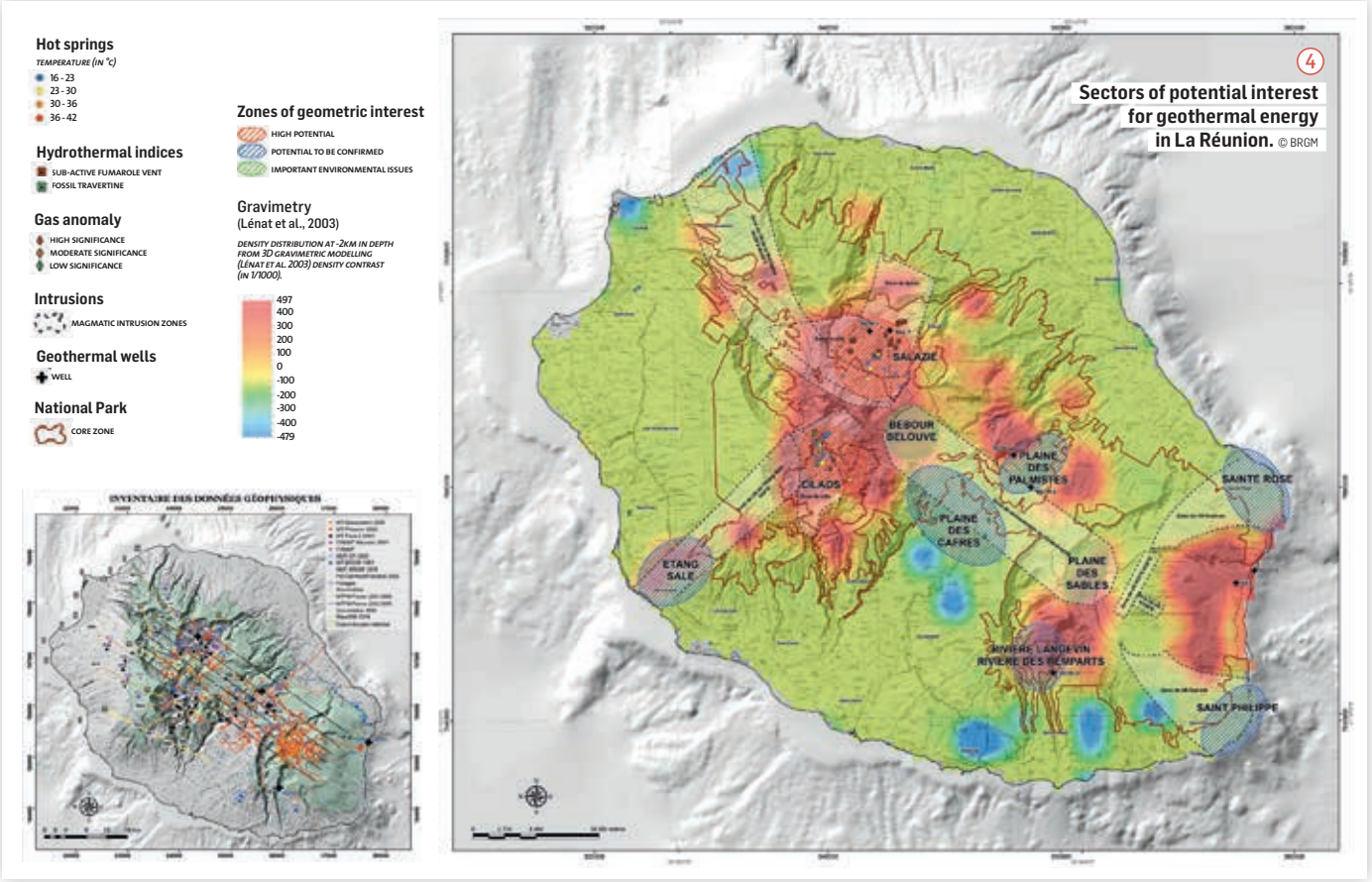
The online filing service for new minimum-impact geothermal installations, on www.geothermie-perspectives.fr. © BRGM

23 EXCLUSIVE PROSPECTING PERMITS VALIDATED OR REQUESTED FOR HIGH-TEMPERATURE GEOTHERMAL RESERVOIRS IN MAINLAND AND OVERSEAS FRANCE IN 2015

NEW REGULATIONS FOR MINIMUM-IMPACT GEOTHERMAL FACILITIES

The BRGM provided assistance for the implementation of new regulations on minimum-impact geothermal installations, in force since July 2015. The online filing service for new facilities (Géothermie Perspectives ADEME-BRGM web site) has already logged over 1000 declarations. The new service uses a statutory national risk map produced by the BRGM and employs Qualit'Enr-certified drilling engineers. Almost 80 of these were trained by the BRGM in 2015.

3 Installing geothermal probes in the city of Auxerre. © BRGM



4 Sectors of potential interest for geothermal energy in La Réunion. © BRGM

A platform to test and optimise shallow geothermal heat exchangers

Mikael PHILIPPE
Project manager and head of the scientific programme run by the technical centre on geothermal energy in buildings

The BRGM's geothermal platform, the only one of its kind in France, was set up in 2008 with support from the Centre Region and the EU, to test the performance of geothermal heat exchangers and to develop innovative tools and methodologies.

The platform is equipped with different types of compact horizontal and vertical heat exchangers connected to thermodynamic machinery capable of reproducing the demands made on the system (heat-pump and building). It is also equipped with a weather station and advanced instrumentation, including a fibre optic network to measure subsoil temperatures.

Improving heat exchanger design

As project manager Mikaël Philippe explains, *"several recent studies have focused on designing geothermal heat exchangers for optimum performance, by simulating different conditions in which they may be used and operated. With Micro-Géo, a project on individual housing run in partnership with the industry, we tested different prototype geothermal tubes connected to the same heat pump. The outcome was a tool, with an interface now under development, that will enable professionals to design solutions according to context (location of the house, surface area, insulation, etc.) and to the demand for hot water, heating and cooling."*

The Corgeosola project (2013-2016) is working to optimise the operation of geothermal tubes buried at depths of 0.8 to 3.5 m, by investigating the influence of the subsoil on heat exchange. "*We set up 2 tubes of different models developed by Terrendis France for Micro-Géo"*, explains M. Philippe, *"one in soil that was optimised by means of a specific compacting technique and the other in ordinary soil, both connected to the platform's thermodynamic system. Testing has now begun and will enable us to assess not only soil conditions but also the moisture conditions most favourable to heat exchange, with a view to improving the placing of the tubes and hence their performance."*

Continuous monitoring

The platform's computer infrastructure is also used for real-time monitoring of heating in a 370 m² renovated building on the BRGM site, supplied by a closed loop system comprising three 92 m wells connected to a heat pump, which in turn is connected to a series of low-temperature radiators. The small difference in temperature between the heat

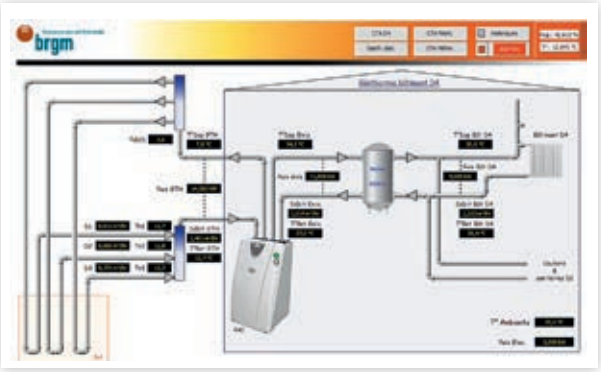
Geothermal tube models tested with the geothermal platform under the Micro-Géo project. © BRGM

Backfilling a geothermal tube at the geothermal platform by watering and compacting with a needle vibrator (Corgeosola project). © BRGM

30°C

WATER TEMPERATURE IN MID-MAY 2016 AT THE OUTLET OF THE HEAT PUMP SUPPLYING THE RADIATORS IN THE BRGM'S D4 BUILDING (OUTDOOR TEMPERATURE: 12.8°C; SOIL TEMPERATURE MEASURED AT THE HEAT EXCHANGER OUTLET: 12.7 °C)

Interface for real-time monitoring of the BRGM building equipped with geothermal heating. © BRGM



"We are finalising a tool that will enable professionals to design geothermal heat exchangers for individual housing"

source (the geothermal wells) and heat emission (radiators) improves the system's energy efficiency. "*The system is equipped with instruments that monitor performance in real time: energy extracted, energy emitted, power consumption, heat diffused, cooling of the liquid, etc.*" explains M. Philippe. "*We are collecting valuable data which will be distributed for training and professional purposes.*" The platform is also used for continuous monitoring of the heating and cooling systems in two chalets equipped with ground-coupled heat exchangers, one connected to a heat pump (air-to-air) and the other to an electrical preheating device that warms the ambient air.

As well as furthering knowledge and bringing continuous improvements to the design and operation of the facilities, these studies are helping to disseminate very low-energy geothermal* power as an essential renewable energy component in the energy mix of the future.

**http://plateforme-geothermie.brgm.fr*

GEOLOGICAL STORAGE
STORAGE IN AQUIFERS
SAFETY CRITERIA
REDUCING CO_2 EMISSIONS
PREDICTIVE MODELLING
EUROPEAN INTEGRATION OF RESEARCH AND REGULATIONS
INTERNATIONAL COOPERATION

"We are developing alternatives to mass centralised storage."

GEOLOGICAL STORAGE

3 QUESTIONS TO

Pierre TOULHOAT • BRGM Deputy Managing Director and Scientific Director

Has COP21 helped to boost interest in geological storage?

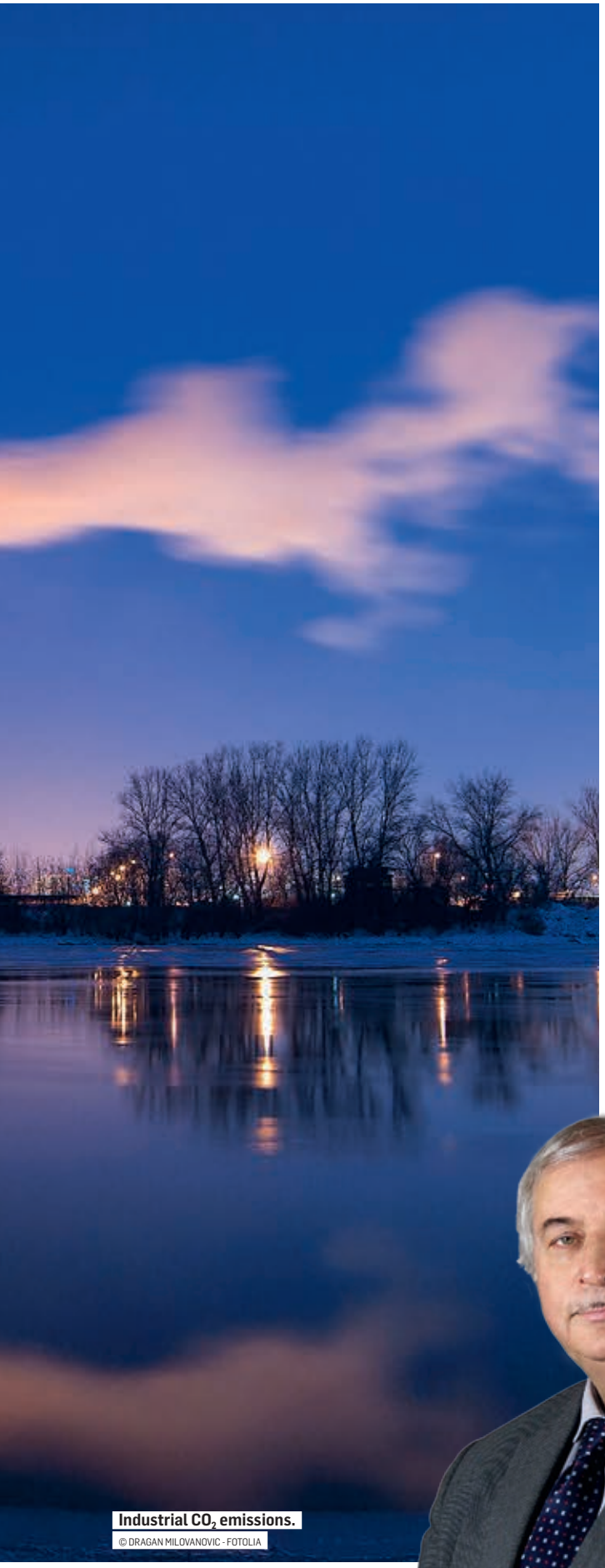
Although the economic context is unfavourable, especially because of the low market price per tonne of CO_2, COP21 issued a strong reminder that storing CO_2 in geological environments is one of the means to achieve the international goals for reducing greenhouse gas emissions. However, the question of its deployment is still at issue. The principle of mass centralised storage in large aquifers is raising a number of scientific questions as well as resistance in society. Studies still need to be made to better characterise the injective properties of these reservoirs and determine the key parameters of guaranteed long-term safety. The means of conveying the CO_2 from different sources to a centralised reservoir also raise questions over investments, facilities and safety.

Are there alternatives to mass centralised storage?

An alternative solution now emerging is to use smaller storage units in geothermal reservoirs located close to certain industrial sources of CO_2 emissions. The idea is to develop small-scale injection systems into geothermal reservoirs whose properties are known, as many are already used to supply heating networks. The BRGM has begun work on this idea with the CO_2 Dissolved project. Other innovative solutions are emerging, such as trapping CO_2 in mine spoil, which is being tested in New Caledonia.

What progress is being made with storing energy carriers?

A 4-year ANR project co-ordinated by the BRGM has just been launched. This is working on large-scale reversible storage of CO_2, CH_4 and O_2 in the EMO systems (electrolysis-methanation-oxycombustion) used to smooth intermittent renewable energy output. Temporary storage of these energy carriers, which can be re-released if needed, raises significant subsoil issues relating to leakproofing, durability and recoverability. In all cases, understanding long-term risks and impacts when developing the solutions considered is a research priority for the BRGM and for the Géodénergies consortium it leads. All these studies are contributing to the draft national strategy for energy research and development.



Industrial CO_2 emissions.

Risk management

The Gerico database has been developed by the BRGM to compile knowledge on remedial measures for underground CO2 storage risks. Gerico was developed for the public authorities, research organisations and industries to help them identify risk scenarios in the specific context of a given site and to develop plans for appropriate remedial measures.

http://gerico.brgm.fr/

CO_2 leakage and groundwater

The Cipres project aimed to characterise the potential impacts of CO2 leakage on groundwater quality in the event of failure of a geological storage site. The digital and experimental approach used has produced interesting results on geochemistry and biogeochemistry aspects, which have been communicated through conferences, publications, a dozen public reports and a methodology guide to the implementation of groundwater monitoring programmes.

Long-term behaviour of an underground CO_2 storage site ②

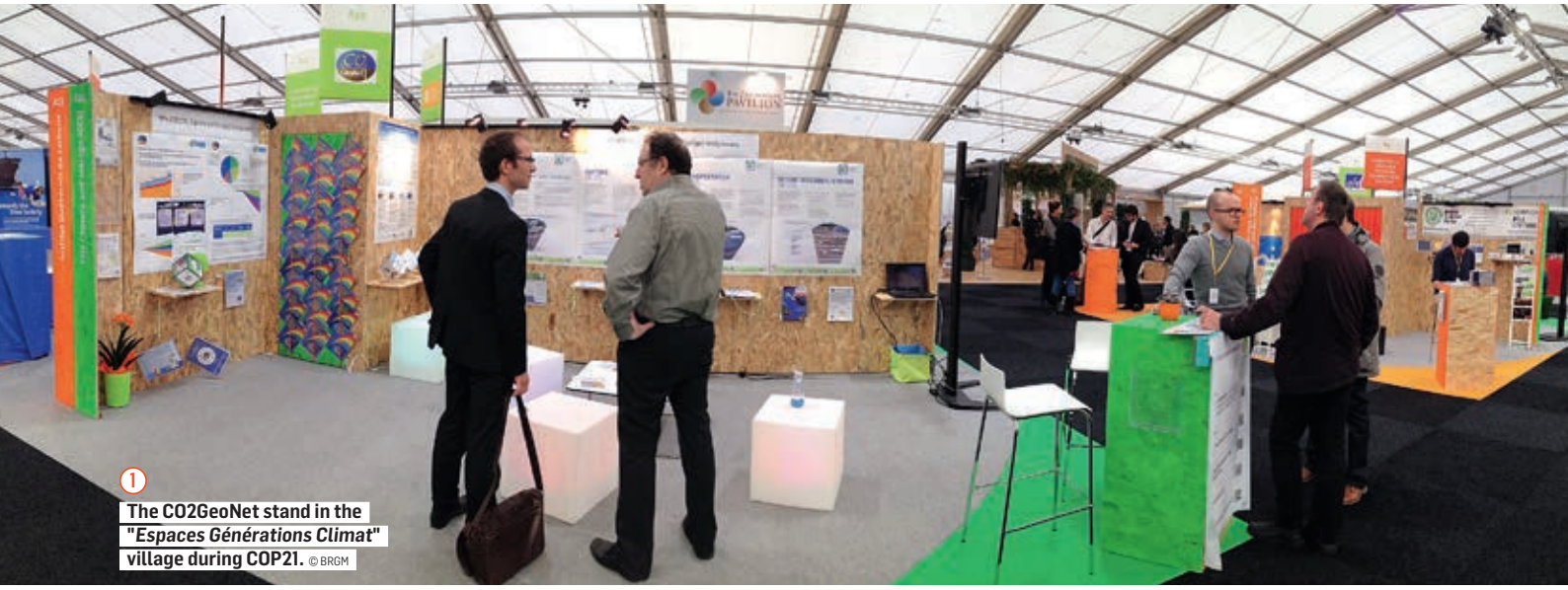
4 years of research were conducted under the European FP7 ULTimateCO2 project involving 12 partners and co-ordinated by the BRGM. The aspects investigated ranged from the fate of the CO2 after injection into the reservoir to the possible impacts of geochemical reactions on caprock and borehole integrity. The project's results were presented at the closing seminar in Paris at the end of October 2015 and compiled into a public report, which is available from the project website.

CO_2 storage and the behaviour of fault zones

The BRGM coordinated the ANR-FISIC project (2012-2015) on the hydromechanical and chemical behaviour of fault zones in CO2 storage contexts. Based on field observations of a natural analogue, coupled digital simulations and innovative laboratory experiments, the project focused in particular on the representation of fault zones in a fractured reservoir, on the combined chemical and mechanical effects of CO2 on the fault zones and on incorporating their hydromechanical and chemical behaviour into a large scale model of the reservoir.

Participation in COP21 ①

The BRGM took part in the COP21 conference in Paris. Through CO2GeoNet (the European network of excellence on underground CO2 storage), two stands were organised in the negotiating area reserved for accredited delegations and in the public "*Espaces Générations Climat*" village, as well as 3 conferences on the contribution of underground CO2 storage to climate change mitigation. The BRGM also took part in the "COP21 Solutions" conference at the Grand Palais. A video on CO2 capture and storage was presented to the public and an interview on this topic was posted online by the national competence cluster on "Education for Sustainable Development".



① **The CO2GeoNet stand in the "*Espaces Générations Climat*" village during COP21.** © BRGM

15

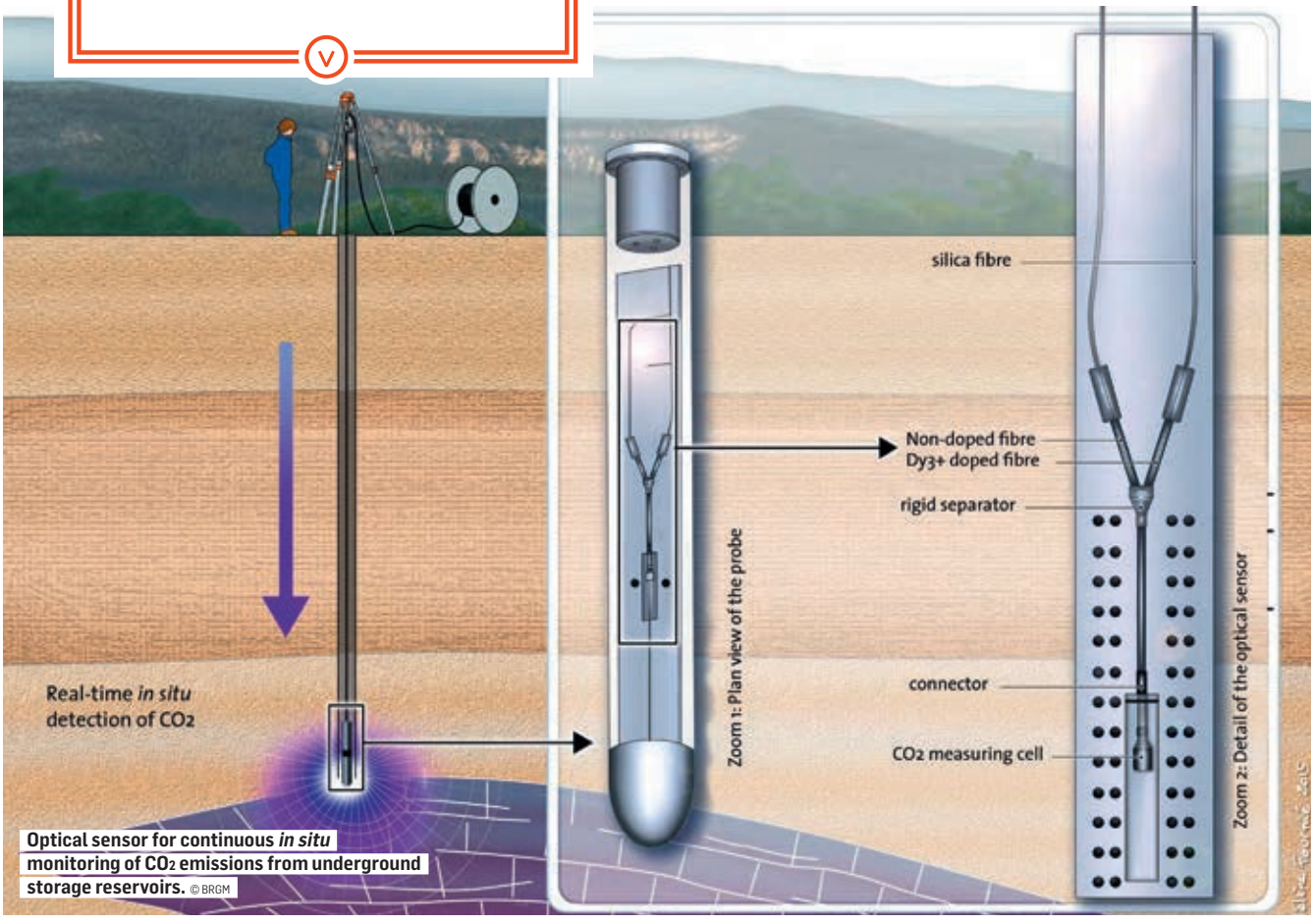
CO_2 CAPTURE AND STORAGE PROJECTS NOW OPERATING WORLDWIDE ARE REDUCING CO_2 EMISSIONS BY 28 MILLION TONNES PER YEAR (GCCSI).

AN INNOVATIVE FIBRE-OPTICS SENSOR FOR CO_2 MONITORING

The "Coptik" project, the fruit of a research and industry partnership supported by the ADEME, is aiming to market an optical sensor for continuous *in situ* monitoring of potential CO2 leakage from underground storage reservoirs. The design of the sensor was made possible by the prior development of an innovative chalcogenide glass fibre with an optical window in the mid-infrared (since CO2 has an intense absorption band extending to 4.3 µm) and an optimum signal/noise ratio. An industrial prototype has now been developed, which the IDIL fibre-optics company, an SME, is planning to launch on the market in 2017.

(2)

ULTimateCO2 investigated the fate of CO_2 injected into a reservoir. Project results at www.ultimateco2.eu



Optical sensor for continuous *in situ* monitoring of CO_2 emissions from underground storage reservoirs. © BRGM

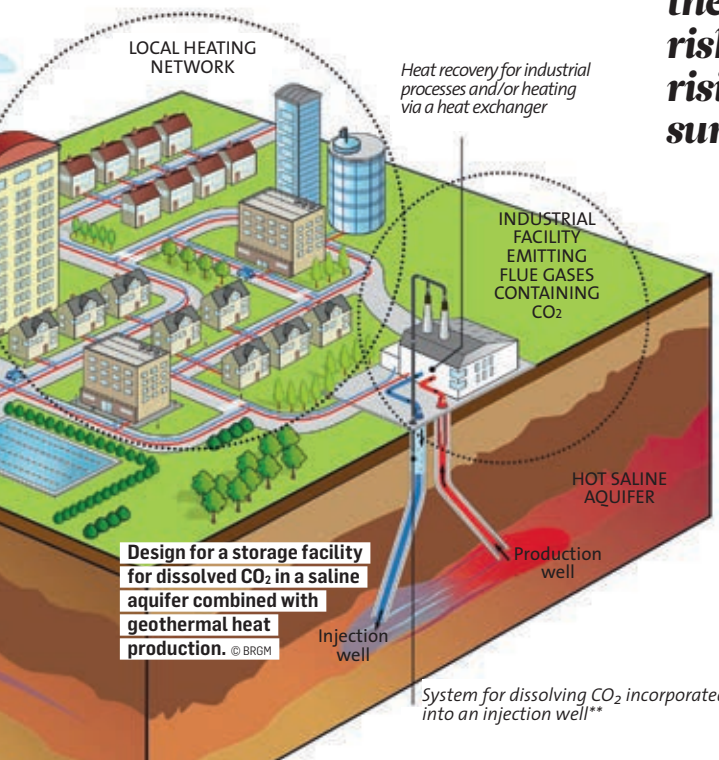
Successfully combining CO_2 storage and geothermal heat extraction

Christophe KERVEVAN
Project manager

Storing dissolved CO_2 in saline aquifers close to industrial emissions sources is the idea being investigated by the CO_2Dissolved project as a promising alternative to large scale storage.

While there is no doubt that geological storage of CO2 is necessary to cut atmospheric greenhouse gas emissions, the implementation, safety and monitoring conditions required raise scientific, technical, economic and social issues that are slowing its development in the short term. Storing CO2 on a small scale close to the emission sources would be an additional and possibly alternative solution. The 3-year ANR CO2Dissolved project explored this possibility.

"Storing dissolved CO_2 in an aquifer avoids the formation of a gas bubble and therefore the risks of gas rising to the surface"



Design for a storage facility for dissolved CO_2 in a saline aquifer combined with geothermal heat production. © BRGM

*System for dissolving CO_2 incorporated into an injection well***

With 7 partners* co-ordinated by the BRGM, the project demonstrated the feasibility of combining the storage of dissolved CO2 in an aquifer with the extraction of geothermal heat.

As project manager Christophe Kervévan explains, "*This solution has several advantages. The idea is to store the CO2 produced by an industrial facility on the same site by injecting it in dissolved form into an underlying deep saline aquifer. The water is pumped up and subsequently reinjected with the dissolved CO2 through one "injection" and one "production" well, similar to the geothermal doublets used to supply heating networks.*"

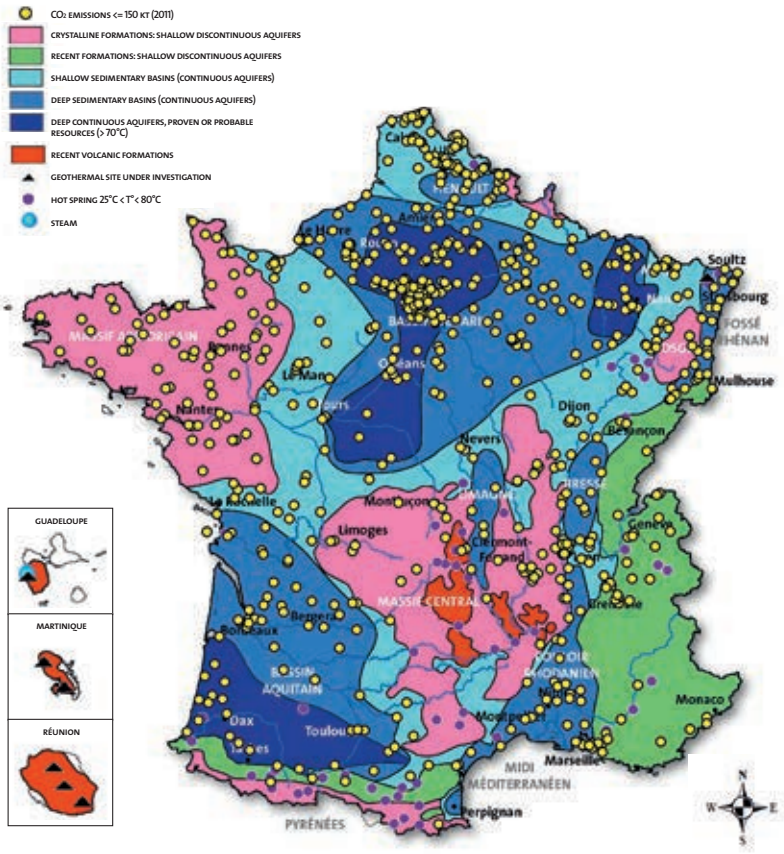
In situ CO2 storage would reduce both the costs and risks of transporting the gas, which, in addition to heat recovery, makes this an attractive solution, subject to the existence of suitable aquifers in the right location and proper control of the process.

Feasibility and risk control

Because CO2 is only is soluble in brine within certain limits, and because of the standard flow rates in geothermal doublets (250-350 m³/h in the Paris Basin), this is a relevant solution for small-scale industrial emissions of CO2 (< 150 000 t/year). The storage sites targeted are deep aquifers (1 500 - 2 500 m) with temperatures in the region of 60 to 80°C. In France, 650 potentially compatible industrial sites (accounting for 25% of emissions in France) have been identified.

"*Our American partners have developed an innovative CO2 capturing process in which water is the only solvent*", says C. Kervévan. "*Possibilities for integrating this process into the CO2Dissolved system have been investigated, and depend on CO2 concentrations in flue gases and the possible need for separation prior to injection. Unlike large-scale sto-*

Map of France matching the locations of low emission industrial facilities - yellow dots - with geothermal resources in aquifers - deep sedimentary basins in blue. © BRGM



rage, where the CO2 is injected in supercritical form, in this case it is entirely dissolved in the brine of the aquifer. This removes the risks of a gas bubble forming underground, which could rise to the surface."

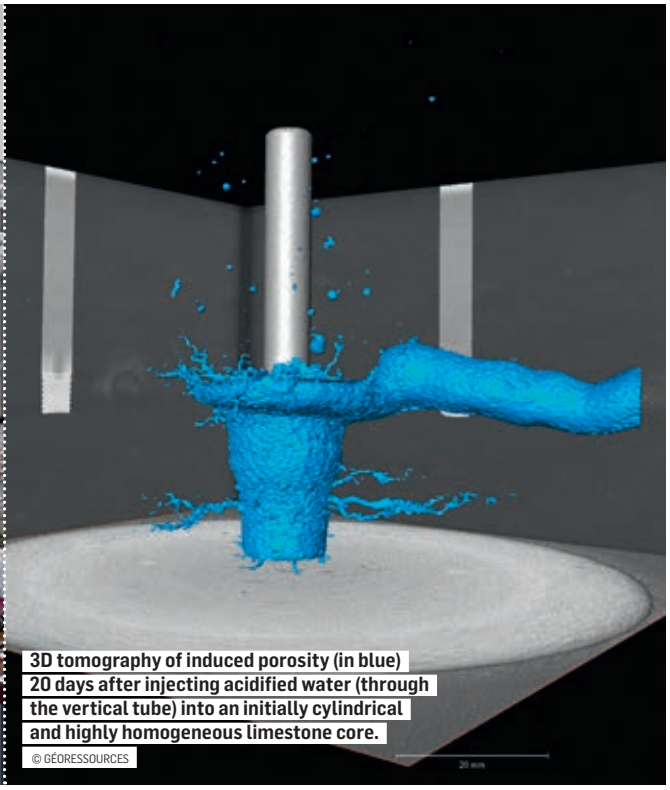
The impacts on the rock of injecting acid water and the resulting chemical reactions that depend on the hydrogeological characteristics of the environment have been digitally simulated and repeatedly tested at an experimental facility. The economic impact has also been investigated, in the case of a sugar mill and distillery in central France, and has demonstrated the viability of most of the scenarios simulated, thanks to the economic benefits of the heat recovered.

"*The next stage*", says C. Kervévan, "*will be to implement a demonstration pilot on an industrial site. The first steps are already under way with the new "Pilot CO2-Dissolved" project financed by the Géodénergies scientific interest group*".

650

POTENTIALLY COMPATIBLE LOW-EMISSION INDUSTRIAL SITES IN FRANCE

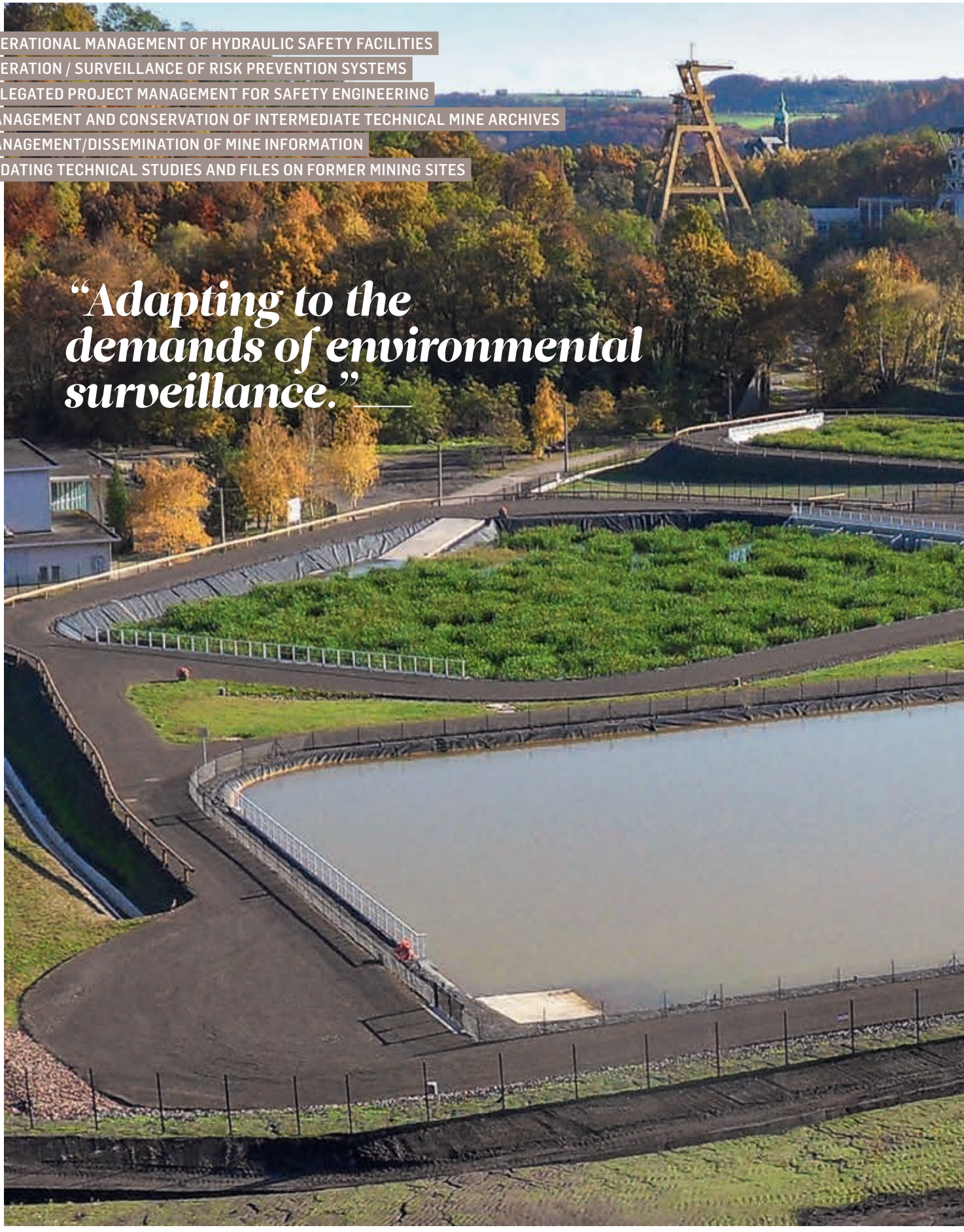
The experimental MIRAGES-2 set-up for injecting a mixture of water and dissolved CO2 into a core under pressure and temperature conditions typical of a deep aquifer. © GÉORESSOURCES



3D tomography of induced porosity (in blue) 20 days after injecting acidified water (through the vertical tube) into an initially cylindrical and highly homogeneous limestone core. © GÉORESSOURCES

** BGR (Germany), CFG Services, Geogreen, GeoRessources, LEO (France), Partnering in Innovation, Inc. (USA).*
*** Technology patented by Partnering in innovation, Inc. (USA).*

OPERATIONAL MANAGEMENT OF HYDRAULIC SAFETY FACILITIES
OPERATION / SURVEILLANCE OF RISK PREVENTION SYSTEMS
DELEGATED PROJECT MANAGEMENT FOR SAFETY ENGINEERING
MANAGEMENT AND CONSERVATION OF INTERMEDIATE TECHNICAL MINE ARCHIVES
MANAGEMENT/DISSEMINATION OF MINE INFORMATION
UPDATING TECHNICAL STUDIES AND FILES ON FORMER MINING SITES



"Adapting to the demands of environmental surveillance."

POST-MINING

3 QUESTIONS TO

Georges VIGNERON • Head of Mine Risks Prevention, Risks and Risk Prevention Division

The DPSM was set up nearly 10 years ago. What has changed in that time?

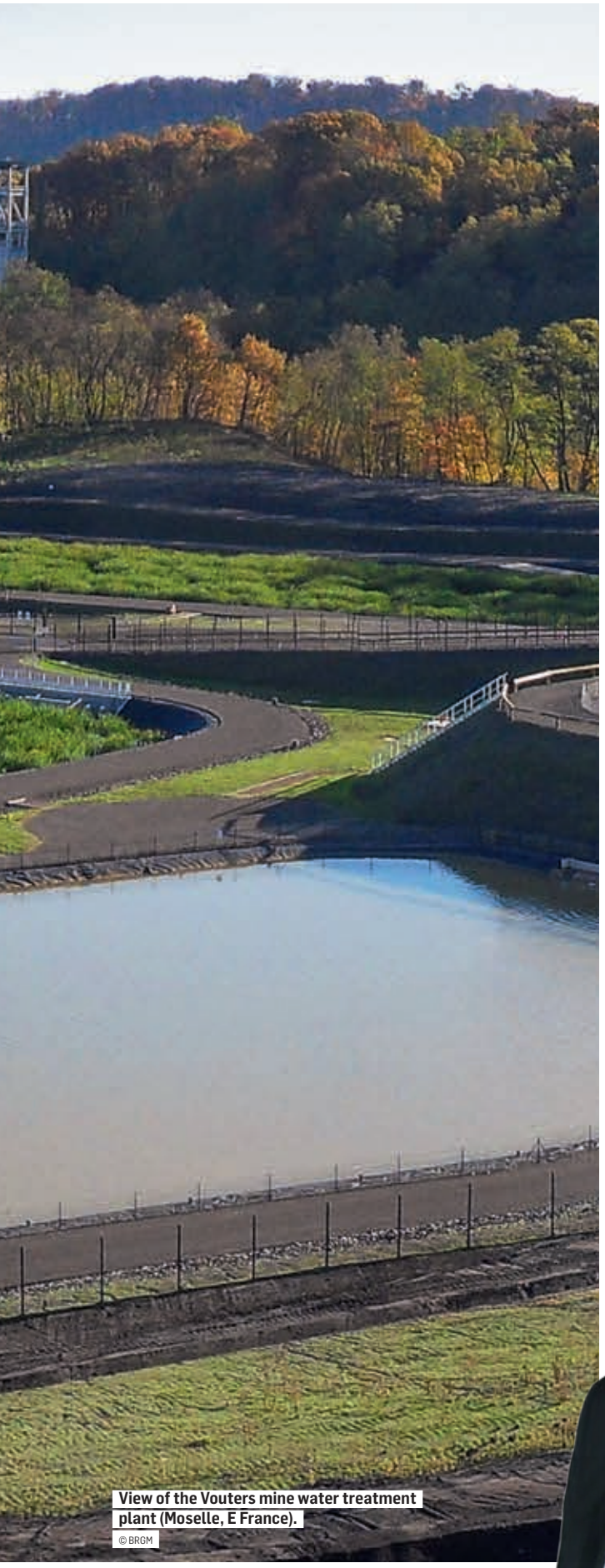
As we move into our 10th year, the DPSM is preparing for the next period of State-delegated responsibilities, starting in 2016. In 10 years the scope of our risk prevention responsibilities has changed continuously and we have had to adapt out competences accordingly. In the next few years, we will clearly be undertaking more diversified missions and applying new monitoring and reporting methods.

How have the DPSM's missions evolved in a context where environmental issues are raising high expectations in society?

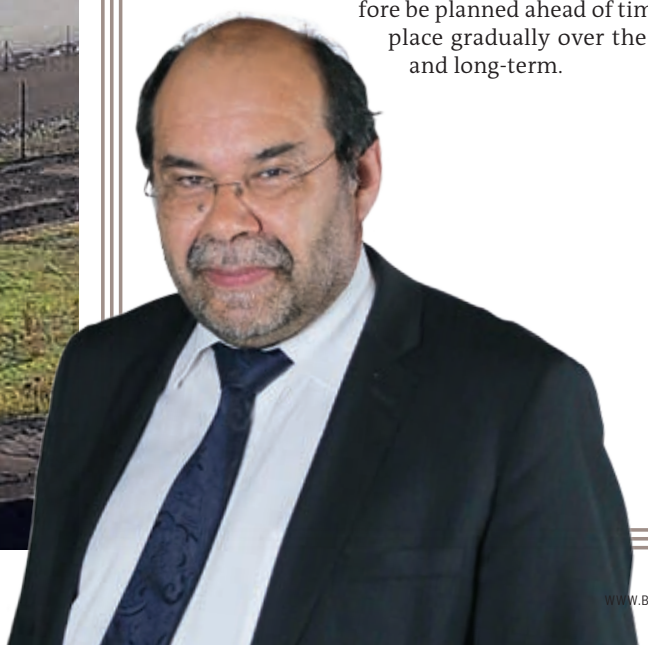
The scope of environmental monitoring is much broader than the classic surveillance of mining risks to people and property, as the aim is to limit and anticipate pollution stemming either directly or indirectly from former mining sites. The DPSM's remit has now been extended to include the management of sites such as Pontgibaud in the Auvergne, the Châtelet gold mine in the Limousin region and La Bellière and Abbaretz in the Pays de la Loire. All of these projects went into the operational phase in 2015. Another typical example of our work is safety engineering to make wells and pits secure (Lochwiller for example). Our responsibilities will be further diversified with the planned addition of other mines now in the process of closure.

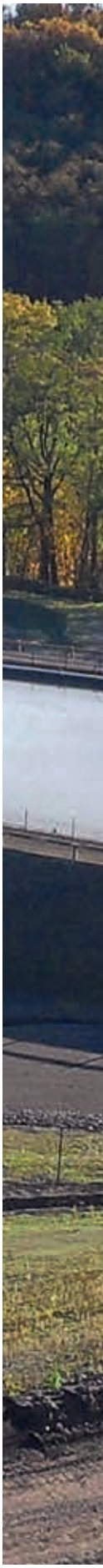
What challenges will these raise for the DPSM?

We will need to identify specific technical know-how among the former Charbonnages de France employees working at the BRGM, whose numbers are naturally declining over time. The challenge will be to transfer their know-how and adapt our recruitment to new scientific and technical needs. To do so, we are implementing tools and methods that require the combined skills of the different teams. The process of adaptation will therefore be planned ahead of time, to take place gradually over the medium and long-term.



View of the Vouters mine water treatment plant (Moselle, E France).





HIGHLIGHTS

Consolidating the Grappon spoil heap ④

The Grappon spoil heap near Meyreuil (Provence, S France), now abandoned, has become unstable since the 1990s and is a threat to traffic on a county road. The DPSM designed a system to secure the spoil heap by removing the earth that had shifted and replacing it with pervious infill. The infill is reinforced by a discontinuous wall of metallic sheet pile anchored into the substratum.

Salsigne: investigating the sources of pollution ①

The Montredon storage area at the Salsigne mine site (S France) began to show signs of arsenic pollution in 2014, extending down to the Orbiel river. The following year, sampling and new analyses confirmed the presence of mineral ores and processing residues that had not been removed. The DPSM began to investigate possibilities for removing the source of the problem.

Surveillance of former mining sites ③

Many different facilities in former mining sites require surveillance, including dykes, pits, spoil heaps, water pumping machinery and reservoirs. This implies a wide variety of manual and automated measurements and observations. The collection and proper archiving of all this information is crucial to effective monitoring in the medium and long term. The DPSM has therefore set up the BDSurv database, to which all the information is sent whatever the method used to collect it.

Moutiers: rehabilitation of the Gorcy neighbourhood

In Moutiers, in the Lorraine iron basin, a sinkhole caused by a sudden cavity collapse led to the expropriation and demolition of several houses and industrial premises, two of which required asbestos removal. Under the Gorcy rehabilitation project, the sound materials are recycled while the polluted materials are sent to treatment facilities.

Reconstruction of the Chemin du Clair pumping station

The DPSM manages 52 pumping stations in the Nord-Pas-de-Calais region on behalf of the State. Its remit is to limit flooding risks. In 2015, reconstruction work began on the Chemin au Clair station, in the municipality of Wingles, to adapt it to the water intake and outlet requirements of new pumping equipment.

Lorraine: dismantling mine gas extraction facilities ②

Mine gas extraction in Lorraine has come to an end. Three sensitive gangways taking the 27 km gas pipeline over a railway and a busy road were dismantled by the BRGM.

1 **Taking water samples from new boreholes at Salsigne (S France).** © BRGM

2 **Dismantling the gangway and pipeline crossing the railway track at St-Avold (Lorraine).** © BRGM

③
BDSurv, the dedicated database for mine site surveillance.
© BRGM

1831

MINE SURVEILLANCE FACILITIES MANAGED BY THE BRGM IN 2015

④ **Installing sheet pile walls to consolidate the northern flank of the Grappon spoil heap (Meyreuil, near Marseille).** © BRGM

MINE WATER TREATMENT PLANTS FOR THE LA BELLIÈRE AND ABBARETZ SITES

The DPSM finalised two management plans for the Pays de la Loire region. Work at the former La Bellière gold mine at Saint-Pierre-Montlimart and the Abbaretz tin mine will commence in 2016. The plans sets out the most appropriate water treatment solution for each site.

The abandoned Abbaretz tin mine (W France) for which a suitable water treatment management plan is in the pipeline. © BRGM

The Vouters Pit: new mine water treatment plant ready to go!

Régis WILSIUS
Project manager, Mine Safety and Risk Prevention

The third of its kind in the Lorraine coal basin, the mine water treatment plant at the Vouters site in Moselle is an improved version of an environmentally compatible passive treatment system. This is a typical example of the work carried out by the BRGM to address new environmental surveillance issues.

For many years, the Vouters mine, which opened in 1855 in the municipality of Freyming-Merlebach in Moselle (E France), was one of the main coalmines in the Lorraine coal basin. The Vouters pit, the deepest in France at 1 327 metres, was active from 1962 to 2003. After its closure, safety work was completed in 2006 and the mine company continued to operate the plant pumping mine water from the central sector.

The Lower Triassic sandstone aquifer underlies the entire Lorraine basin, reaching down as far as the impermeable Permian formation beneath. The carboniferous formation from which the coal was extracted is older than the Permian layer, which was fractured during mining operations, causing water from the aquifer to filter through into the mine workings. The water was pumped continuously to the surface so that mining could continue. When the mine closed, pumping also ceased, leaving the water to flood the underground chambers.

An improved environmentally compatible passive treatment system

To maintain the quality of the groundwater, it therefore became necessary to infiltrate water "artificially" into the mine reservoir to prevent the formation of mineralised plumes in the water and to control its rise to the surface, which is endangering derelict facilities around the mine. The Vouters treatment plant is the third of its kind in the Lorraine coal basin. Its purpose is to treat the mine waters to reduce their iron and manganese concentrations before they are released into the environment. The plant uses an environmentally compatible passive treatment system.

Cascade aeration, settling ponds and lagoons

The mine water pumped out of the reservoir is characterised by high concentrations of dissolved iron and manganese leaching out from iron pyrites. Iron and manganese are both water-soluble and precipitate after aeration, clouding the water with typically orange-coloured particles of iron hydroxide. The treatment plant reduces these iron and manganese concentrations to the permitted sta-

The settling ponds where iron oxides and suspended matter sink to the bottom. © BRGM

tutory levels (1 mg/l for manganese and 2 mg/l for iron). The treatment process at Vouters is referred to as "passive", since the oxidised particles settle naturally as the water moves through the different stages. The mine water is first channelled down a series of four aeration cascades, which allow for flexibility in the operations.

Studies by the post-mining unit for Eastern France (UTAM Est) have produced innovations in this area. For example, the cascades have hollow steps to improve aeration and reduce turbulence. The water then flows into settling tanks where the iron hydroxide and other suspended matter fall to the bottom. The mine water, with a much reduced iron concentration, is then channelled into lagoons. These are planted with reeds whose extensive root systems complete the passive treatment process by filtration and oxidisation. By using broad nozzles, the water is evenly sprayed across the surface of the tanks and lagoons, which improves the settling process. After about two days of passive treatment, the purified water can be released into the environment, after tests for quality and quantity at the lagoon outlets.

A pumping station. © BRGM

Results are very promising and the plant is now treating the mine water at a rate of 200 m³/h, which will increase to 500 m³/h in future. Treatment efficiency is fully in line with expectations. New features are in place to guarantee safety during the periodic sampling and maintenance operations undertaken by the plant managers.

4 M€

COST OF THE 2-YEAR PROJECT INCLUDING STUDIES, 100 000 M³ OF EARTHWORKS AND LAYING A 2 KM PIPELINE

Cascades with hollow steps that improve aeration and the precipitation of iron particles. © BRGM

"Results are very promising and the plant is now treating the mine water at a rate of 200 m³/h, which will increase to 500 m³/h in future"

UNDERSTANDING AND MAPPING GEOLOGICAL AND COASTAL RISKS
DESIGNING SURVEILLANCE SYSTEMS AND PREDICTIVE MODELS
DELIVERING DATABASES
VULNERABILITY ASSESSMENTS
ASSESSING CLIMATE CHANGE IMPACTS
SAFETY ANALYSES OF UNDERGROUND STORAGE SITES AND SUB-SURFACE WORKINGS
RISK ASSESSMENTS AND RISK REDUCTION
THIRD-PARTY EXPERT STUDIES ON NATURAL AND UNDERGROUND STORAGE RISKS
POST-MINING EXPERT STUDIES

"Risks are a social as well as a scientific challenge."

RISKS

3 QUESTIONS TO

Jean-Luc FOUCHER • Director, Risks and Risk Prevention Division

With the Sendai Conference and COP21, the Risks Division has had an eventful year. What has been the outcome?

The UN conference on disaster risk prevention, held in Sendai in Japan, set out a global framework with 3 goals: protection of all the world's populations and their living environment, a significant reduction in the number of deaths and people affected and a substantial reduction in economic losses and material damage. These commitments were strongly echoed during COP21, which clearly pointed to climate change and its consequences in terms of the scale and frequency of natural disasters as factors in the breakdown of societies.

How are the BRGM and the Earth Sciences responding to these challenges?

We need to review the way we collect and analyse data at the operational level, to provide spatial planners with governance and risk management tools that also take behavioural sciences into consideration. Our R&D work is looking to new technologies and new tools and models backed up by experimental and demonstration platforms. Societal aspects are the other challenge: the measures recommended to cope with the consequences of disaster must be genuinely acceptable. This means building closer links with users, who can also produce useful input to our thematic databases through interactive applications and web portals.

What are your main ongoing projects?

Coastal areas and sensitive site imaging are among the most significant, such as the request for a reassessment of nuclear facilities from the French nuclear safety authority, following the Fukushima disaster. Follow-up on the main COP21 commitments concerning global risks is another important line of work. We are also making more and more use of the sensor functions of tablets and smartphones, which are now widely used by our fellow citizens. In disaster situations, these can be decisive for crisis management. The issue is to manage the channels and information flows from social networks in real time. This means developing algorithms capable of processing and validating keywords relating to such events.

A landslip triggered by the presence of underlying gypsum (Le Luc, S France). © BRGM

HIGHLIGHTS

Earthquake risks in Haiti

The seismic micro-zoning programme was completed in 2015, with the delivery of micro-zoned maps for 5 cities in northern Haiti. The BRGM also assessed their vulnerability to seismic activity and put forward strengthening solutions accompanied by significant skills transfers to the State of Haiti. Finally, we produced an atlas of natural risks (earthquakes, tsunamis, coastal flooding and land movements).

Volume 5 of the report on "Climate in France in the 21st Century" ②

For Volume 5 of the report on "Climate in France in the 21st Century" (on climate change and sea level: from global change to French coastlines), the BRGM piloted the chapters on consequences of sea level rise: coastal flooding, erosion and retreat of sandy and loamy coastlines, saline intrusions in coastal aquifers and needs for coastal infrastructure adaptation.

Managing the risks of CO_2 leakage in urban environments

The CO2-Clermont project is mapping gas emissions (mainly CO2) in the Clermont-Ferrand urban area and providing technical support to manage the risks that arise. A measurement campaign showed that the emission zones are highly localised and that concentrations can vary substantially within a few metres. A preventive approach based on targeted action with accompanying information for the public was recommended.

Characterising cyclone hazards in La Réunion

The BRGM is coordinating the ANR SPICy project, which is developing a forecasting system for coastal and river flooding due to cyclones on the island of La Réunion. With its partners (Météo France, LACy, BRLi and the Ales Mining company), it developed a transdisciplinary modelling approach to the entire risk cycle based on weather forecasts, coastal and river flooding predictions and crisis management scenarios.

New remote sensing techniques to monitor volcanic eruptions ③

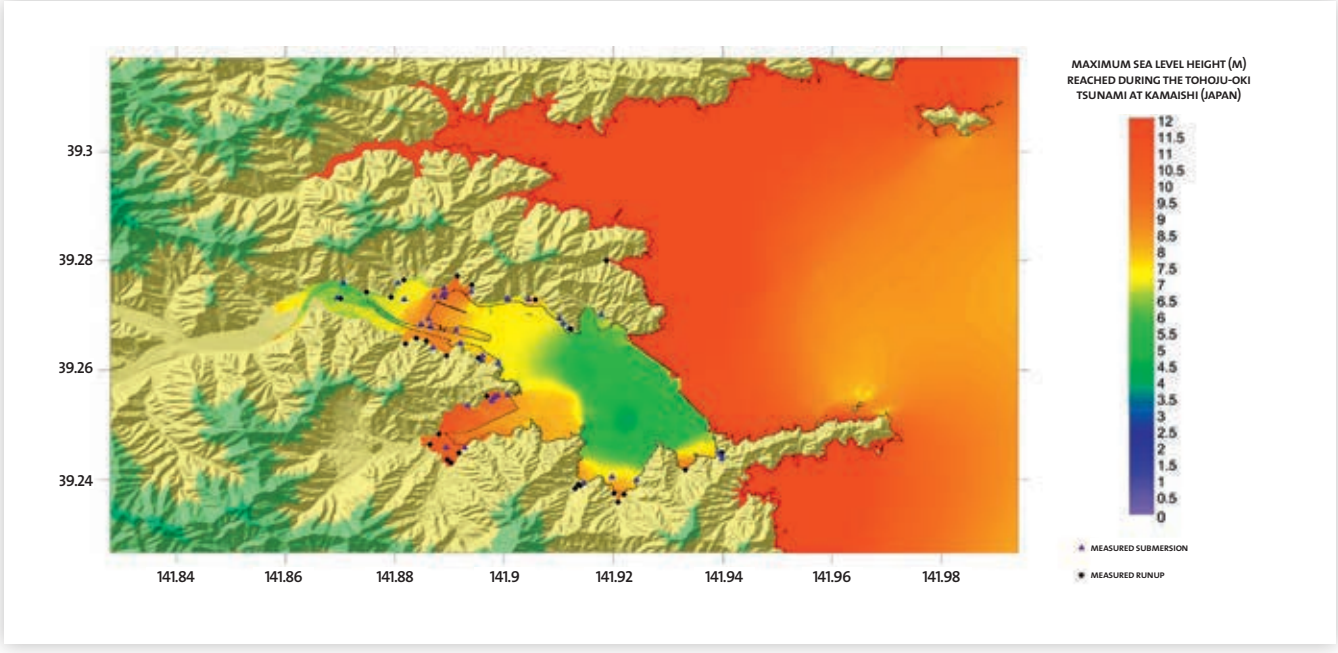
The ability to make exact calculations of the volume and topography of volcanic ash plumes is crucial to assessments of eruption hazards. A new analytical method based on correlating satellite images was developed by the BRGM under the FP7 Aphorism project. This highly innovative method can be used to extract a plume elevation model (PEM) of the volcanic ash.

Assessing tsunami impacts ①

The Tandem project, which involves 10 partners under CEA coordination, is assessing the potential effects of a tsunami on French coastlines, especially the Channel and the Atlantic coasts where several nuclear power plants are located. In 2015, the BRGM worked on the tsunami in Japan (Fukushima 2011) and the coastal flooding it caused, and updated knowledge on the 1755 Lisbon earthquake and tsunami.

①

Simulation of tsunami impacts on Japan's coastlines. © BRGM

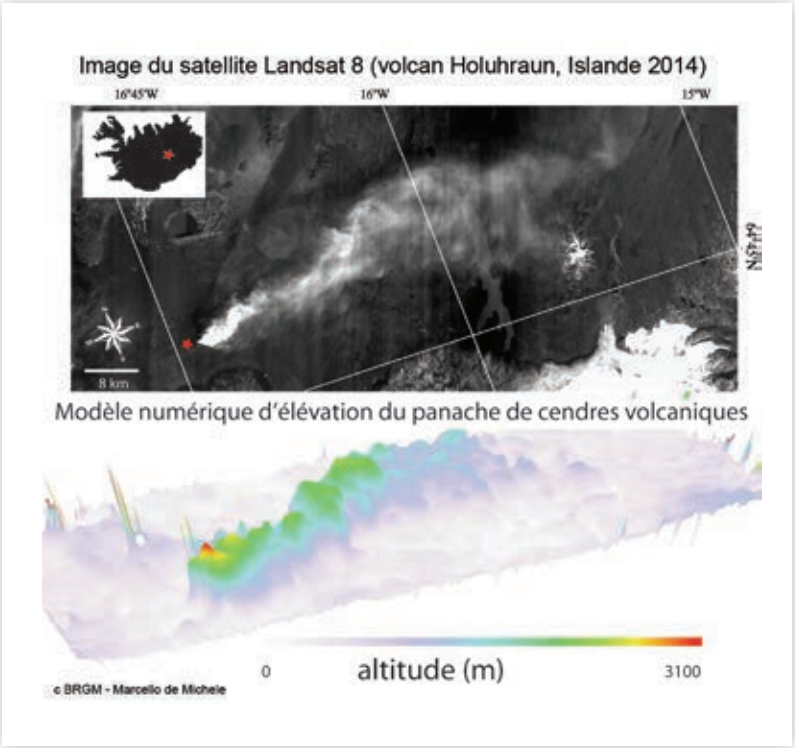


1.7 mm

SEA LEVEL RISE FROM 1901 TO 2009 (TO WITHIN 0.2 MM/YEAR).

② **Presentation of Volume 5 of the report on "Climate in France in the 21st Century". The BRGM piloted the chapters on the consequences of sea level rise.** © MEEM

③ **Eruption of Holuhuraun volcano (Iceland, 2014) photographed by Landsat 8 (NASA/USGS) and corresponding Plume Elevation Model.** © BRGM



NEW TECHNOLOGIES TO MONITOR SANDY COASTLINES AND DUNES

To improve monitoring of storm impacts on sandy coastlines, the BRGM developed a method involving drone technology, image processing and GPS acquisitions to 1 cm accuracy. Two campaigns were conducted in 2015 during the March and September high tides along the Atlantic coast (Vendée, W France), in partnership with the Azur Drones company. The drone campaign produced a digital terrain model and a very high resolution orthophotograph.

Drones can be used to acquire the digital terrain models needed to monitor sandy shorelines and dunes. © BRGM - AZUR DRONES

A multimethod geophysics survey to detect and characterise karsts

Jean-Michel BALTASSAT
CEA Gramat project manager

Kévin SAMYN
Head of the seismics component

Thomas JACOB
Head of the gravimetrics component

The BRGM was commissioned by the Atomic Energy and Alternative Energies Commission (CEA) to conduct a survey combining several geophysical methods in order to identify the karst conduits that determine underground water flows beneath its industrial facility in Gramat (SW France).

To improve its management of the risks arising from the presence of an underground karst network, the CEA commissioned a study from the BRGM to improve geological knowledge of the site by detecting and characterising the underground karst system, with a particular focus on active conduits from upstream to downstream.

"*Speleological investigations had already been made*", says Thomas Jacob, the project's co-manager, "*but only upstream from the facility, so that questions remained about the network taken as a whole. We decided to combine several geophysical methods involving non-invasive techniques deployed from the surface. The survey began in 2014 with a combination of seismic reflection and refraction with electrical tomography of the conduits previously identified by the speleologists, to provide benchmarks for the investigation.*"

Tests having demonstrated the validity of the combined techniques, the BRGM turned in 2015 to the unexplored downstream parts of the system, covering an area of about 1 km².

Combining seismics, electrical tomography and gravimetrics

"*We deployed three methods that complement each other by focusing on different properties of the karst environment, adding gravimetrics to the two methods used for the first phase*", explains T. Jacob. "*Refraction and reflection seismics, which involve recording the propagation of shock waves produced by small explosions or physical shocks using*

"We applied an original and effective approach to detect karstic cavities by combining three geophysical methods that complement each other by their sensitivity to different properties of the terrain"

Gravimetric measurements and differential GPS location at the CEA site in Gramat. © BRGM

a network of geophones, enabled us to produce a vertical section of the subsoil down to about 400m; the different rates of propagation tell us what kind of rock - weathered, karstified, etc. - the shock waves are travelling through. This gives us an initial approach to the structure and variations of mechanical properties in the subsoil."

Electrical tomography measures the propagation of an electrical current in the subsoil via electrodes placed along the segment under investigation. This produces an image of resistivity in the ground, which reflects variations caused by moisture content, weathering, lithological features, etc.

Finally, gravimetrics measure variations in the gravitational field - in this case every 50 metres using a GPS - arising from the way masses are distributed in the subsoil.

Conclusive results

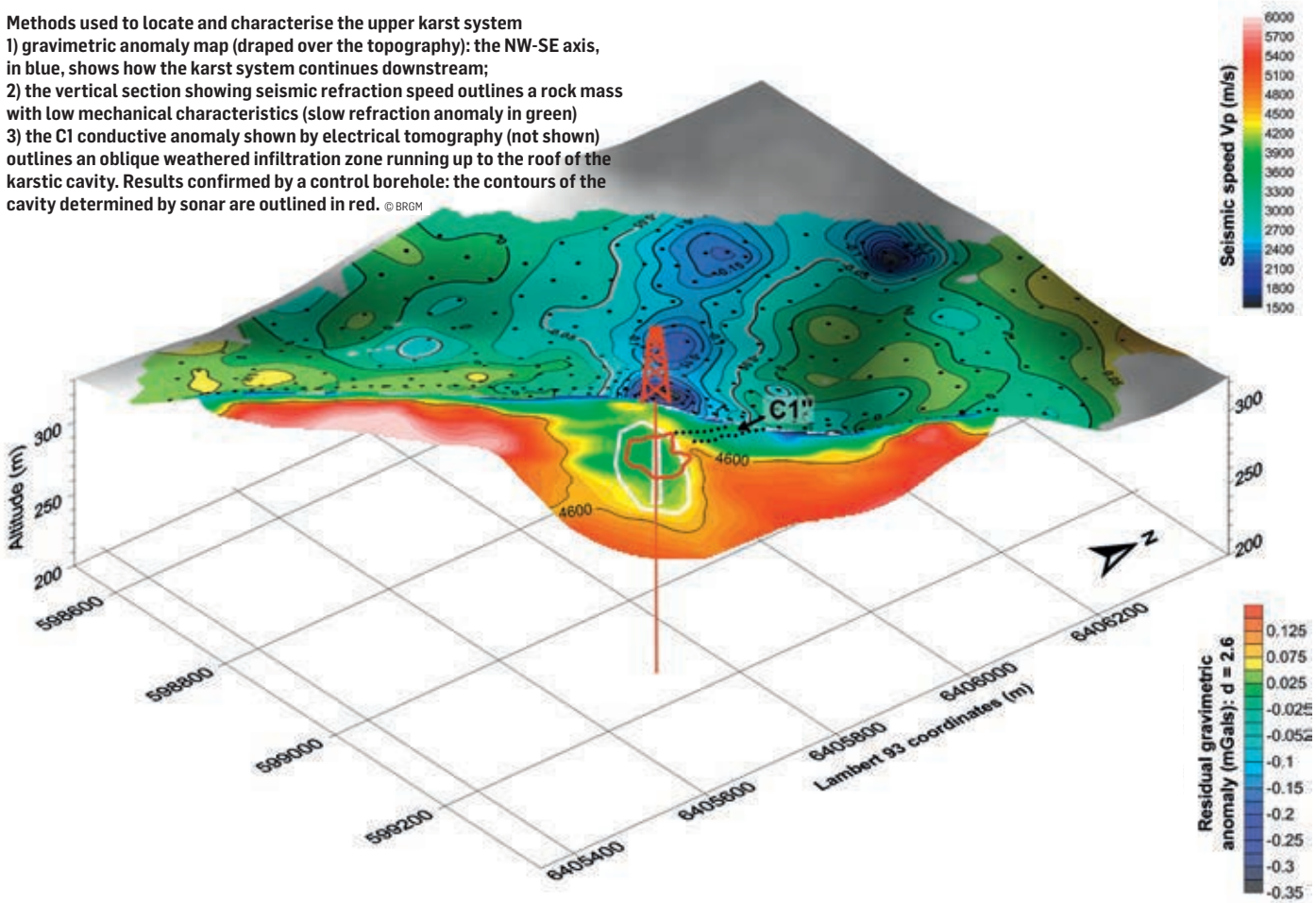
"*Once collated into a GIS*", explains T. Jacob, "*the different results revealed significant anomalies along the axis of the main cavities in the site, reflecting the continuity of part of the karst system downstream from the industrial facility. The most significant geophysical anomaly detected by our methods along this axis was confirmed by drilling a borehole down into one large cavity and several smaller cavities and clay passages further down.*"

The complementary contributions of the three methods confirmed the relevance of combining seismics, electrical tomography and gravimetrics to investigate complex systems such as karsts. The results are conclusive for the upper karst system (down to 20 m) but further investigations are needed to characterise the anomalies detected at greater depths (150 m) in the flooded lower karst.

6 500

LINEAR METRES OF SEISMIC AND ELECTRICAL PROFILES AND 556 GRAVIMETRIC POINTS OVER A SURFACE AREA OF 1 KM²

Methods used to locate and characterise the upper karst system
1) gravimetric anomaly map (draped over the topography): the NW-SE axis, in blue, shows how the karst system continues downstream;
2) the vertical section showing seismic refraction speed outlines a rock mass with low mechanical characteristics (slow refraction anomaly in green)
3) the C1 conductive anomaly shown by electrical tomography (not shown) outlines an oblique weathered infiltration zone running up to the roof of the karstic cavity. Results confirmed by a control borehole: the contours of the cavity determined by sonar are outlined in red. © BRGM



HYDROSYSTEM FUNCTIONING
RESOURCE MONITORING, PIEZOMETRIC NETWORK
MAPPING FOR THE FRENCH HYDROGEOLOGICAL REFERENCE BASE
GEOCHEMISTRY DOCUMENT COLLECTION
PROCESSED DATA PRODUCTS
UNDERSTANDING THE BEHAVIOUR OF DIFFUSE POLLUTION
CONCEPTUAL MODELS
PREDICTIVE RESOURCE AND TRANSPORT MODELLING
INTEGRATED AND ACTIVE WATER RESOURCE MANAGEMENT
TRANSBOUNDARY WATER RESOURCE MANAGEMENT
WASTEWATER RE-USE AND ALTERNATIVE RESOURCES
ECONOMIC ASSESSMENTS AND MANAGEMENT SCENARIOS
DECISION-SUPPORT TOOLS

"Climate change has created needs for new water management tools."

WATER

3 QUESTIONS TO

Nathalie DÖRFLIGER • Director, Water, Environment and Ecotechnologies Division

Climate change has created needs for new kinds of water management. Can you give some examples?

On the quantitative resource management side, we now need to work with adaptation scenarios, to analyse changes in land use and water demand or needs for artificial recharge for example. We need platforms to run new integrated modelling tools. The Aqui-FR platform, for example, pools hydroclimatic modelling tools and existing hydrogeological models for different French regions (in partnership with Météo-France and IPSL-UMR METIS among others). With this platform, new climate services can be developed and the results presented dynamically through online portals.

And these developments are 100% BRGM innovations?

Some of the hydrogeological modelling applications used in Aqui-FR were developed by the BRGM over several decades. They are designed to integrate different models of hydrosystem functioning, to deterministic, global or semi-global resolutions. The innovation is that the different hydrogeological and climatic models now interact through their interfaces. They are part of the toolkit developed by the BRGM, which includes applications to characterise aquifers, dynamically or in terms of transport or recharge. These applications are available on line as technical support for professional hydrogeologists.

Will there be new tools developed in the future?

More work is needed on modelling to link the 3D models to BDLISA, the database of hydrogeological units in France, which is linked in turn to the French Geological Reference Platform (RGF). We are also looking to analyse adaptation measures to refine economic and environmental assessments. These tools being developed for the future will reinforce the BRGM's acknowledged position as a major player in the circular economy and the management of France's water footprint.

Aerial view of the Trou de Fer (La Réunion) after heavy rainfall.

New online software for hydrogeologists ④

To provide technical support for professional hydrogeologists, the BRGM offers free access to its tools to help design field operations and interpret measurements:
- OUAIP, to interpret pumping trials
- TRAC, to interpret groundwater tracing results
- ZAPPEL, to plot contributing zones and isochrones created by groundwater pumping
- TIGRE, to calculate hydrodynamic interference between several boreholes
- CATHERINE, to simulate the influence of fluctuations in the level of a river or water body on the associated water table
- GARDENIA, a global reservoir model to simulate flow rate history or piezometric levels of springs and rivers and calculate recharge
- GESFOR, to create the sections and reports needed to file drilling projects
- ESPERE, to estimate effective rainfall and aquifer recharge.

www.brgm.fr/logiciels

Monitoring network for rivers in the Jura ①

Water quality in the rivers of the Jura uplands has declined spectacularly, causing episodes of very high mortality in the last five years. With the QUARStIC project, the BRGM set up a surveillance network to monitor the quality of surface and groundwater at five stations in the Loue catchment basin. Aim: a better understanding of nutrient transfers in karst aquifers and rivers, in particular using spectro-UV probes for continuous measurements of nutrients and organic matter.

SAPH PANI in India ②

In 2011, India, with the European Union, launched a project called SAPH PANI, meaning "clean water" in Hindi. The aim was to improve systems for infiltrating treated water into natural basins in semi-arid or bedrock contexts, by removing pathogenic microorganisms and organic and metal pollutants. After conceptualising the system by means of isotopes in particular, the BRGM, with the CEFIRES (Hyderabad, Telangana), developed an aquifer management and recharge model (AMR), using MARTHE for 3D simulations of the infiltration of temporary surface water, in continuity with the non-saturated zone and evaporation.

Participation in the World Water Forum and COP21

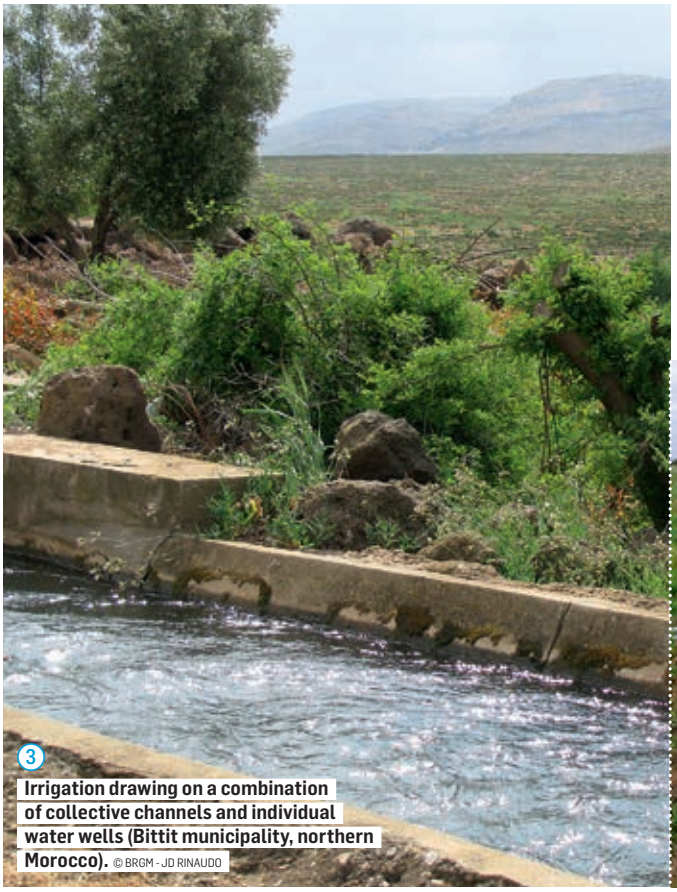
The BRGM took part in the World Water Forum in South Korea as a member of the French delegation with the French Water Partnership. It contributed in particular to two scientific and technical sessions, sharing its know-how on piezometric networks, on interpreting groundwater data using a HYPE-type tool, and on flood management in karst areas with the Nîmes project as an example. It also took part in debates and presentations on water resource management in the climate change context, at scientific events organised by the MENSR and ALLENVI during COP21 in Paris in December.

ARENA: irrigated agriculture in North Africa ③

The ANR ARENA project investigated the sustainability of the irrigated farming now developing in North Africa with increasing access to groundwater. The BRGM analysed the trajectories of economic development in these agricultural regions and the vulnerability and resilience of farmers, to put forward joint management strategies for re-establishing sustainable groundwater use, particularly in the Sefrou region in Morocco.

① **Setting up the QUARSTIC surveillance network at the source of the Loue river.**
© BRGM - JEAN-BAPTISTE CHARLIER

② **Taking readings of field data collected by the network monitoring the infiltration basin.**
© BRGM - ADRIEN SELLES

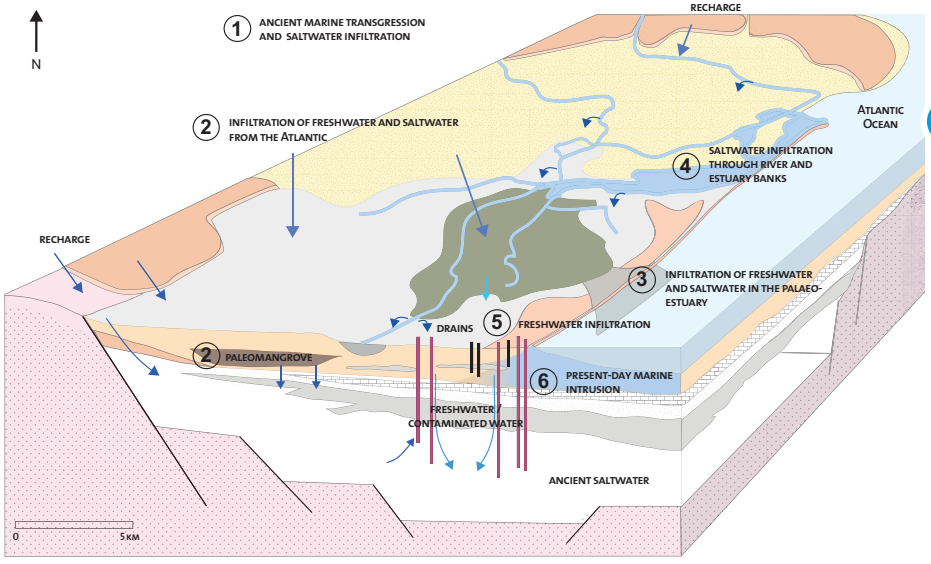


3 Irrigation drawing on a combination of collective channels and individual water wells (Bittit municipality, northern Morocco). © BRGM - JD RINAUDO

110 BILLION M³/YEAR

FRANCE'S WATER FOOTPRINT: THE VOLUME OF WATER NEEDED TO PRODUCE ALL GOODS AND SERVICES USED BY THE FRENCH POPULATION

4 A tracing test. © BRGM



Conceptual model of aquifers in the Recife urban area showing springs and salination processes.

© CARY ET AL., 2015 : CARY, L., PETELET-GIRAUD, E., BERTRAND, G., KLOPPMANN, W., AQUILINA, L., MARTINS, V., HIRATA, R., MONTENEGRO, S., PAUWELS, H., CHATTON, E., FRANZEN, M., AUROUET, A., 2015. ORIGINS AND PROCESSES OF GROUNDWATER SALINIZATION IN THE URBAN COASTAL AQUIFERS OF RECIFE (PERNAMBUCO, BRAZIL): A MULTI-ISOTOPE APPROACH. SCIENCE OF THE TOTAL ENVIRONMENT 530–531, 411-429.

PROTECTING COASTAL AQUIFERS IN BRAZIL

The Franco-Brazilian ANR COQUEIRAL project brought a better understanding of the mechanisms involved in the deterioration of groundwater resources in the Recife region. The project investigated the functioning of the reservoir in terms of recharge and circulation, identifying springs and salination processes and the mechanisms governing contamination due to human activities, using a multi-isotope approach. Aim: to help water agencies improve their management tools to ensure long term protection.

Towards more accurate predictions of climate change impacts on water resources

Nadia AMRAOUI
Hydrogeologist and manager of the programme on predictive water resource scenarios, Water, Environment and Eco-technologies Division

In today's context of predictable climate change, assessing groundwater recharge and seasonal forecasts of water resources are essential to anticipate and manage groundwater in a precautionary and sustainable way. The BRGM is involved in a series of studies aiming to meet increasing social expectations in this area and to address the increasingly severe consequences of climate related events.

"Aqui-FR", "Recharge AERMC" and "MétéEAU des nappes" are three complementary and emblematic BRGM research projects, currently at different stages but all working towards the same goal of developing scientific responses to growing social expectations concerning water resources and increasingly severe climate-related events.
Climate change could have serious impacts on water resources, both on the surface and underground. The issues variously concern the quantity and quality of water resources, pressures exerted, climate change itself, drought, groundwater flooding and needs for the most recently acquired data.

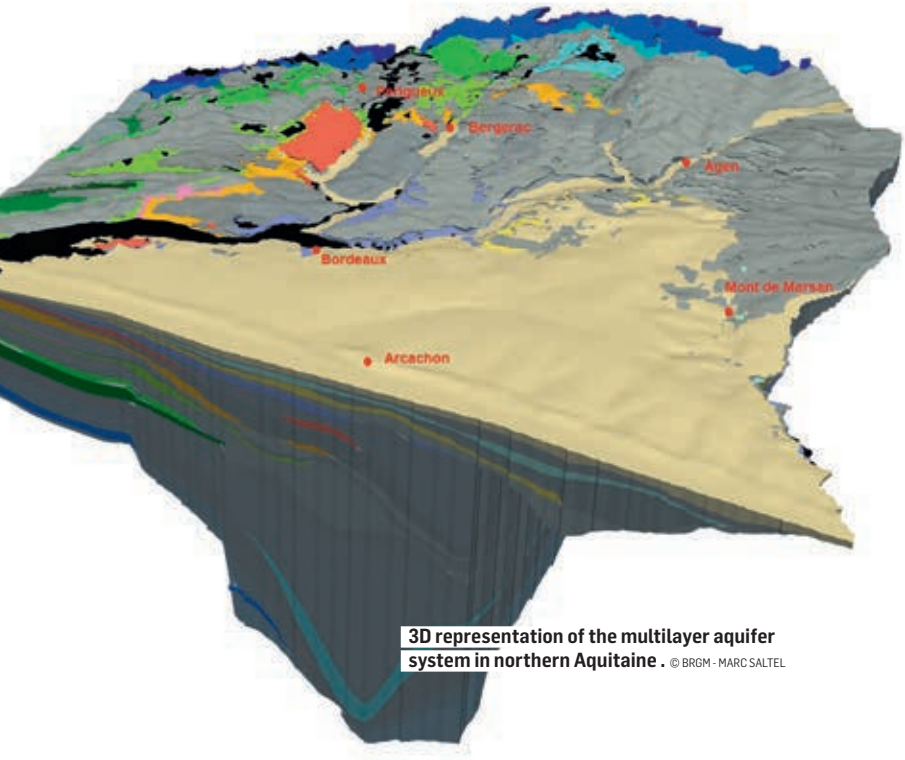
Predicting trends in groundwater levels and simulating different climate change scenarios

These tasks raise considerable challenges. In France, groundwater supplies two thirds of all drinking water and 40% of the water used in agriculture and industry (energy production not included!). Groundwater also plays an important role in the regulation of aquatic areas on the surface, by compensating low surface water flows as well as sustaining wetlands. Declining groundwater recharge, which could be a consequence of climate change, could therefore have an impact on hydrological processes in every compartment of the water cycle.
Aqui-FR, partnered by Météo-France and IPSL-UMR METIS in particular, aims to develop a national platform for regional hydrogeological modelling covering a significant proportion of mainland France. Its aims include testing different modules for calculating recharge and simulating a series of climate change scenarios. The goal is to produce 10-day to seasonal groundwater forecasts, and ultimately to project trends over several decades to come. Aqui-FR has already demonstrated the feasibility of integrating different regional hydrogeological applications

Water resource studies to predict climate change impacts: the Sautadet Falls.
© BRGM - FRANÇOIS MICHEL

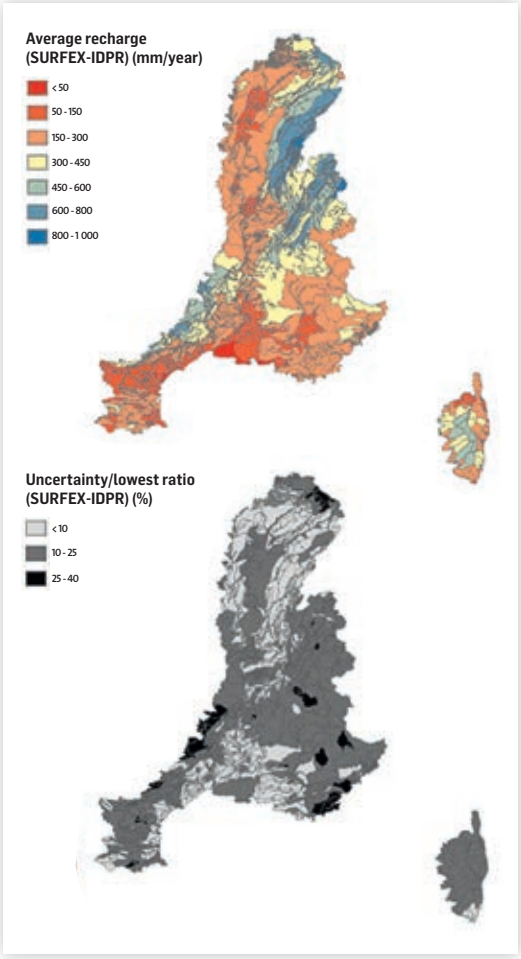
64%

OF DRINKING WATER DISTRIBUTED IN FRANCE IS SUPPLIED BY GROUNDWATER



3D representation of the multilayer aquifer system in northern Aquitaine . © BRGM - MARC SALTEL

Map showing recharge of BD-LISA hydrogeological units in the Rhone-Mediterranean-Corsica basin and associated uncertainties over the choice of effective rainwater infiltration ratios. © CABALLERO ET AL., (2016).



into a common platform, with a view to processing the data for monitoring, forecasting and climate projection purposes. The next stages will be to produce realistic forecasts and to distribute them in real time. Further studies will also aim to complete aquifer coverage within the platform and to assess results over a long retrospective period.

"Declining groundwater recharge, as a consequence of climate change, could have an impact on hydrological processes in every compartment of the water cycle"

Climate change impacts on aquifers in the Rhône-Mediterranean-Corsica basin

The Recharge AERMC project is working to assess the predictable impact of climate change on aquifer recharge in the Rhône-Mediterranean-Corsica basin, by implementing a series of recharge estimation methods developed to handle the different type of aquifers found in the region. A map has been produced showing future annual recharge across the basin. This shows how far aquifer recharge will decline according to different climate scenarios: an overall drop of -5% to -25%, with the most severe impacts in sectors such as the west of the Languedoc-Roussillon region and Corsica.

Finally, the BRGM's MétéEAU research project on water table forecasting is delivering raw and processed data from the national piezometric network in near real time. The aim is to link these data to weather information and data on river flow rates. One outcome could be the production of commercially available maps and graphs showing predictions of high and low surface water levels.

POLLUTION IMPACTS AND RISK ASSESSMENTS
INTEGRATED WASTE MANAGEMENT – RECYCLING / RE-USE PROCESSES
SECONDARY RAW MATERIALS – DEPOLLUTION TECHNIQUES
INVENTORY OF ABANDONED MINING SITES – BIOGEOCHEMISTRY OF POLLUTED ENVIRONMENTS
ENVIRONMENTAL MANAGEMENT OF POLLUTED SITES, SOILS AND SEDIMENTS
ASSISTANCE TO REGULATORY DEVELOPMENT
THIRD-PARTY EXPERT STUDIES AND SUPPORT TO PUBLIC ADMINISTRATION – DECISION-SUPPORT TOOLS
ENVIRONMENTAL ASSESSMENTS

"Ecotechnologies are crucial to "urban mining" and therefore to the circular economy."

ENVIRONMENT AND ECOTECHNOLOGIES

3 QUESTIONS TO

Francis GARRIDO • Deputy Director, Water, Environment and Ecotechnologies Division

Urban mining seems to be taking off. How are ecotechnologies contributing?

They are crucial! Urban mining is increasingly coming to the fore in the development of the circular economy. Characterising, managing, recovering and reusing waste, especially from the construction sector, is of particular importance and there is a need to develop specific sectors of activity to support spatial planning and environmental conservation. The BRGM is a long-standing player in this field, developing new technologies to characterise and separate waste as well as new processes to recover and recycle the different materials.

Are there specific problems with electrical and electronic waste?

These materials are typical "urban mining" resources. Widespread use of digital technologies is steadily increasing the quantities of waste from electrical and electronic equipment (known as WEEE), from which rare earth elements and metals can be recovered and recycled.
In this area, for example, thanks to our specialist know-how on recycling mine waste, the BRGM is developing a process to fragment e-cards in order to recover the copper, gold, silver, palladium, tin, tantalum, etc. they contain. These are true breakthrough technologies. For example, the REMETOX project, winner of the Phase 2 award in the World Innovation Competition 2030, is now moving towards validation, at the pilot scale, of the process for recycling metals from e-cards using supercritical water.

But much still needs to be done to industrialise these eco-technologies...

Technological innovation needs to go hand in hand with studies on the economic aspects of the processes developed, involving industries at an early stage. This is why the BRGM conducts most of its technological innovation projects with industries, from SMEs to major groups, to facilitate the technology transfers that are the ultimate goal of our work.

Electronic and electrical waste makes up one of the resources of what is known as "urban mining".

Launch of the ATIM-HUNAN project in China ①

The ATIM-HUNAN project, involving French research teams (BRGM as coordinator and the University of Tours) and Chinese teams from ASEM Water, the Hunan agricultural university and the Centre-South university, is setting up long-term collaborative projects on the mining environment, with a view to implementing an integrated regional remediation strategy.

PACMAN project on contaminated sites ③

The BRGM contributed to the PACMAN project (with the University of Lorraine, coordinated by the University of Umea in Sweden), which was selected under the third call for projects from the European SNOWMAN research network on characterising the behaviour of polarised polycyclic aromatic compounds in contaminated soils. The aim was to understand the transfer of these harmful compounds into water and to conduct a cost-benefit analysis of management and remediation techniques for contaminated sites.

POLPHARMA project: treating micropollutants in surface water

With the increasing quantities of pharmaceutical residues in wastewater, further refining processes are needed in addition to wastewater treatment in plants that were not designed to handle pollutants of this kind. This is the aim of POLPHARMA, an ANR project conducted in partnership with two industrial groups (Solvay and Suez Environnement) and four research centres (BRGM, CEREGE, IEM and UPMC). The consortium is working to introduce an innovative process involving nanomaterials to eliminate emerging micropollutants (such as antibiotics) from liquid effluent.

Linking household consumption and waste management

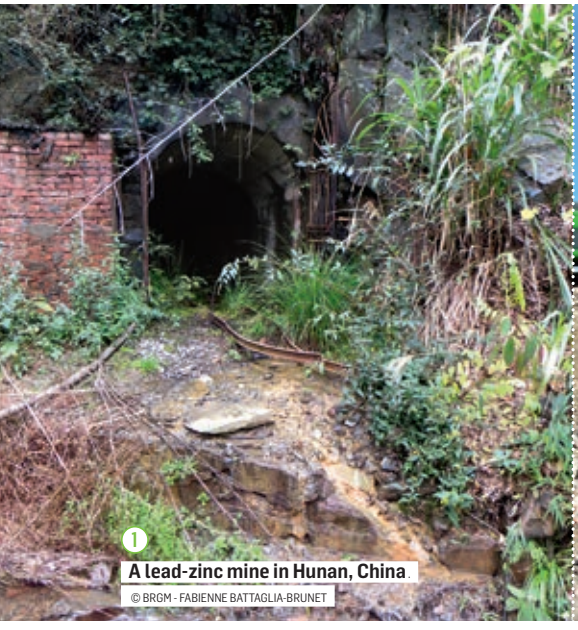
The REACTIVITY project, cofinanced by the ADEME, is investigating the apparently conflicting aims of increasing household consumption and public policies to prevent and manage waste. The project analysed the conditions in which household consumption could be decoupled from waste production. The studies ranged from initial purchases by individual consumers to the performance of economic activities in terms of generating and managing waste.

Treating mineral ores: the PROMETIA network ④

The BRGM is one of the founder members of the European PROMETIA network, which is coordinated by the CEA. This is a network of some thirty European industrial groups, SMEs, research organisations and universities with a leading role in the treatment of mineral ores, extractive metallurgy and recycling. The aim of the network is to boost the development of innovative, environmentally compatible and socially acceptable technological solutions for the treatment of mineral ores, through extractive metallurgy techniques applied to ores and industrial and urban waste.

Recycling construction waste: BRGM involvement in new European projects ②

The BRGM is one of the 25 organisations partnering the Horizon 2020 HISER project, coordinated by Tecnalia (Spain). The aim is to develop and demonstrate innovative, integrated and cost-efficient solutions for recycling demolition waste.



① **A lead-zinc mine in Hunan, China.**
© BRGM - FABIENNE BATTAGLIA-BRUNET

② **Recycling concrete demolition waste for road-building.**
© BRGM

50 MILLION TONNES

OF WASTE PRODUCED EACH YEAR IN FRANCE BY THE CONSTRUCTION SECTOR WITH ONLY 50% RECYCLED AT PRESENT

3 **Using a hydraulic shovel to collect samples of earth contaminated by polycyclic aromatic hydrocarbons.** © BRGM - STÉFAN COLOMBO

4 **Opening seminar of the European PROMETIA project in Brussels.**

© PROMETIA

Checking mercury concentrations in the ambient air of a classroom.

© BRGM – PAULINE BALON

SENSITIVE FACILITIES PROGRAMME (ETS): OVER 1000 DIAGNOSES BY MID-2015

Under the national Health and Environment Plan, the French State is piloting activities to verify the quality of soils, water and ambient air in "sensitive facilities", i.e. those used by children and adolescents and built on or close to former industrial sites. The Ministry of the Environment delegated project management responsibility in this area to the BRGM in 2010, for 5 years. By mid-2015, the BRGM had conducted 1200 diagnoses of "sensitive facilities".

Biotechnologies to support materials recovery and environmental quality

Fabienne BATTAGLIA-BRUNET
PhD in microbiology, programme manager with the Water, Environment and Ecotechnologies Division

Yannick MÉNARD
PhD in process engineering, programme manager with the Water, Environment and Ecotechnologies Division

With overall demand for high-value metals and minerals steadily increasing, biotechnological solutions are being developed not only to improve their extraction from mineral ores, mining effluent and waste but also to aid decontamination. The BRGM is working on several lines of research involving innovative bioprocesses.

Since the end of the Second World War, demand for mineral resources has steadily increased. The industrialised countries are now facing a very tense supply situation, while demand from emerging economies is rising fast. Environmental issues also demand eco-responsible development strategies. As a result, scientists are being called upon to find solutions based on circular economy principles to help preserve the environment.

Biotechnology developments are producing original and effective solutions, for example for recycling mine waste and recovering secondary raw materials, such as electronic waste, *via* "urban mining". Solutions are also being developed to remedy industrial contamination in the environment (soils and water).

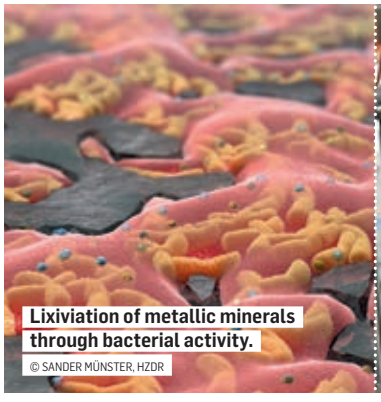
"The projects conducted with the BRGM are introducing innovative and eco-efficient bio processes"

Innovative and eco-efficient bio-hydrometallurgy processes

A wide range of techniques exist that involve bacterial processes. Bio-hydrometallurgy, which includes biolixiviation, is one example: the technique involves using microorganisms (bacteria), which transform solid metals into liquids that can then be extracted from rock and other materials. A significant amount of primary copper is now produced in this way. Biolixiviation can also be used to recover and recycle mine spoil, thus optimising mineral extraction, and to extract certain metals from e-cards, in line with circular economy principles. The ANR Ecometals, BIOCOMET, LIXO2 and Ingecost-DMA projects, conducted by or with the BRGM, are good illustrations. All these projects are working on innovative and eco-efficient processes.

Recovering rare and strategic metals

The Franco-German ANR Ecometals project, partnered by the BRGM and Helmholtz-Zentrum Dresden-Rossendorf (HZDR), is exploring possibilities arising from the fact that mining residues contain quantities of metals like copper, nickel, zinc, silver, cobalt, gallium and gold that are not insignificant in the current context of scarcity. To use them, new methods have to be developed to



Lixiviation of metallic minerals through bacterial activity. © SANDER MÜNSTER, HZDR

A series of batch reactors used to study the physicochemical phenomena involved in the biolixiviation of sulphide ores. © BRGM

optimise their recovery. Bio-hydrometallurgy is one solution. The laboratories involved are working on biolixiviation to extract copper from ores and mine waste in Germany's Kupferschiefer and from complex polymetallic deposits in France (copper and associated metals).

The aim is to develop alternative treatment methods and demonstrate their effectiveness, cost-efficiency and viability for ores containing strategic industrial metals, and to develop new environmental analysis tools to demonstrate the eco-efficiency of the new technical options proposed compared to current practices.

15%

SHARE OF WORLD COPPER SUPPLIES PRODUCED BY BIOLIXIVIATION

Biolixiviation of e-cards

Other projects to develop bioprocesses are also under way at the BRGM. LIXO2, conducted with several industrial partners, is also aimed at recovering mine waste, using a particular type of biolixiviation. BIOCOMET, which is the subject of a thesis with the Paris Higher National School of Chemistry, is developing a biolixiviation system to recover rare metals from e-cards.

Finally, the Ingecost-DMA project: as well as solid mining residues (potentially containing recoverable metals), mineral extraction can pollute aquatic environments with metals and metalloids. Methods need to be developed not only to recover these valuable substances, but also to treat the polluted water. The project, which involves Hydroscience Montpellier, the BRGM, the IMPMC, IRH Environnement and Sol Environnement, is working on the integrated management of mine tailings and arsenic-laden acid mine drainage. Here again, protecting the environment is also the aim. Innovative combinations of biological processes are under development.

Crushing e-cards prior to recovering the metals they contain. © BRGM

ORGANIC AND INORGANIC CHEMISTRY – EMERGING POLLUTANTS
NANOPARTICLES – ON-SITE AND CONTINUOUS MEASUREMENTS
PASSIVE SAMPLERS AND SENSORS
MINERALOGY AND CRYSTALLOGRAPHY – GEOCHRONOLOGICAL DATING
ISOTOPIC TRACING – MICROBIOLOGY AND MOLECULAR BIOLOGY
MULTI-SCALE BIOGEOCHEMICAL EXPERIMENTATION
PILOT FACILITY FOR TREATMENT PROCESSES

"Developing our role as a provider of value-added services."

LABORATORIES AND EXPERIMENTATION

3 QUESTIONS TO

Hervé GABORIAU • Director, Laboratories Division

The BRGM's Laboratories and Experimentation Division is developing its role as a service provider. Why?

Increasingly, the strategy for research laboratories with the Carnot label is to offer integrated and value-added services to meet growing demand from our clients and partners. The idea is not to offer one-off services, but rather to cover an entire development process, from advice at the inception stage through to critical interpretations of results.

Are any new trends emerging in the topics you handle?

The BRGM is being called on to deal with new and complex subjects, such as emerging pollutants or the characterisation of highly heterogeneous and reactive metallurgical waste. This means we have to deploy complementary analytical approaches in several fields at once, such as chemistry, physical chemistry, mineralogy and isotopes, based on field and laboratory measurements and specific experiments. Our work continues beyond the analytical results as such, to understand the underlying processes. The approach used also has to be tailored to each specific problem and designed to cover all the issues raised.

Is your "market" likely to evolve?

We are constantly adapting our services to meet the needs of our clients and partners, whose activities benefit in turn from our research and expert studies, for example on metrology for the circular economy or tracing of environmental and human processes. Together with the acquisition of new equipment, these developments are enhancing our capacity to meet the needs of both public and private players.

The experimental LABBIO set-up for environmental biogeochemistry analyses.

HIGHLIGHTS

ORIGAMI, developing a molecularly imprinted polymer

Under the ANR Ecotech ORIGAMI project, with the ICOA (Institute of Organic and Analytical Chemistry), Suez and Affinisep, the BRGM contributed to the development of a molecularly imprinted polymer that can select for AMPA (aminomethylphosphonic acid) and glyphosate by passive sampling.

ISCR to reduce chloredecone concentrations in banana plantations

Applying an "In Situ Chemical Reduction" process can reduce total concentrations of chlordecone in the contaminated soils of banana plantations by 74%. Radishes grown on these soils, once decontaminated, had chloredecone concentrations below the maximum threshold for residues and could therefore be consumed.

Micro-characterisation of bacterial biofilms ④

Scanning Transmission Electron Microscopy (STEM) was used to understand the interactions that take place during biolixiviation between bacterial biofilm marked with gold and particles of sulphide ore.

RAMAN palaeothermometry adopted for the RGF programme ①

The BRGM is pursuing its efforts to calibrate a palaeothermometer via RAMAN spectroscopy analysis of carbonaceous matter. Aim: to test the robustness of the method in different geological contexts: orogenic, multiphase thermal episodes, pressure effects. The method has been adopted for the French Geological Reference Platform (RGF).

Deploying the "Gaz o Gaz" sampler in Algeria ②

Under the project to monitor the geochemistry of the Continental Intercalaire aquifer in the Algerian Sahara, the BRGM produced diagraphs using multiparameter probes and the "Gaz o Gaz" fluid sampler at depths of up to 340 metres.

Loire Basin: tracing the origins of metal contaminants ③

The ISOP 2 project, funded by the Loire-Brittany Water Agency and the BRGM, is developing a method to identify the sources of metals (zinc, copper and lead) found in the Loire Basin. Aim: to assess, by applying an innovative isotopic method, the complex processes that govern the distribution of metal particles in water, how they fix to sediments and how they may become re-suspended.

BRGM publications in a special issue of the *Procedia Earth and Planetary Science* journal

The International Applied Isotope Geochemistry conference (AIG-11), organised in September 2015 by the BRGM under the aegis of the International Association of Geochemistry (IAGC), covered topics ranging from isotopic geochemistry and hydrogeology to georesources and climate change.
The 23 Class A articles produced by BRGM researchers were published for the occasion in a special issue of the *Procedia Earth and Planetary Science* journals (Elsevier).

① **RAMAN spectroscopy.** © BRGM – DIDIER DEPOORTER

② **Deployment of the Gaz o Gaz sampler in the Algerian Sahara.** © BRGM - ALAIN GADALIA

10 000

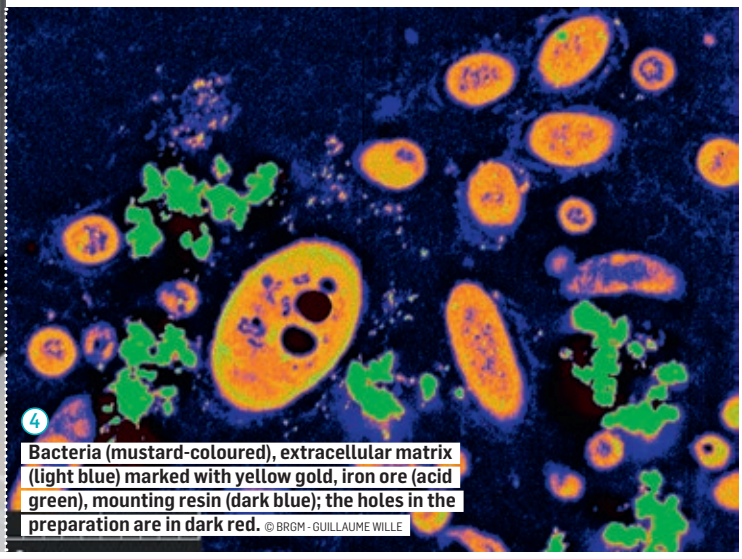
AVERAGE NUMBER OF PEAKS IN A CHROMATOGRAM OBTAINED BY HIGH-RESOLUTION MASS SPECTROMETRY

HIGH-RESOLUTION MASS SPECTROMETRY FOR STATUTORY MONITORING

Under Aquaref, the BRGM demonstrated the usefulness of high-resolution mass spectrometry to identify and quantify organic pollutants at low concentrations, including metabolites and degradation products. This innovative technique could prove to be an efficient way of detecting substances of interest by simplifying the substantial workload required to prioritise the target molecules.

High-resolution mass spectrometer. © PHILIPPE NEGREL

3 *In situ* measurements of physico-chemical parameters in the Loire Basin. © BRGM - ROMAIN MILLOT



4 Bacteria (mustard-coloured), extracellular matrix (light blue) marked with yellow gold, iron ore (acid green), mounting resin (dark blue); the holes in the preparation are in dark red. © BRGM - GUILLAUME WILLE

PRIME, an innovative experimentation platform to boost understanding and action

Catherine CROUZET
Head of the Experimentation Unit, Laboratories Division

Christophe MOUVET
PIVOTS programme director with the Water, Environment and Ecotechnologies Division

Organising an experimental approach - designing the experimental set-up, conducting the tests, monitoring, analysing and interpreting the results - is no simple matter. The BRGM's longstanding know-how in this field is illustrated by the PRIME project for a multiscale experimental platform for environmental metrology to be developed at the Orléans site.

Experimentation is essential in scientific research: it is what enables researchers to reproduce the way a reactional system functions, by means of tests run at different scales through closely controlled systems.

Reproducing natural environments in the laboratory

Because the soils, water tables and geological formations found in natural environments are highly complex systems, they are extremely difficult to investigate. Reducing the complexity of these systems is the fundamental purpose of experimental approaches. When applied to a wide range of environments, experiments complement field studies by limiting the number of uncontrolled parameters and producing appropriate limit conditions for model-building, for example.

"The PRIME platform comprises innovative experimental equipment including a multi-metric pilot which is the only one of its kind in France"

Columns to study pollutant transfers in sediments.
© LAURENT MIGNAUX - MEDDE

Experiments can have multiple aims: to identify and quantify the mechanisms that govern the way a system evolves, to measure changes in a given state caused by human pressures or to assess the responses of an environment to a rehabilitation or remediation option.

BRGM: a strong culture in the experimental field

Over the years, the BRGM's teams have developed a strong culture in the field of experimentation. The BRGM stands out for its multidisciplinary approaches, which account for the originality of its experimental approach compared to other scientific laboratories. Another original feature is our "expe-

rimental loop" concept. The problem to be resolved (management of a contaminated site for example) is first identified on the ground, then studied in the laboratory to find solutions that can be implemented back on the ground.

Our experimental approach can be illustrated in numerous ways: for example, our laboratories work on the fate and treatment of pollutants such as pesticides, nitrates, arsenic and emerging substances in the subsoil, on trapping chemical elements in clay barriers, on the stability of waste materials subject to weathering, and so on.

To do so, the BRGM has experimental facilities for tests ranging from the laboratory scale (centrimetric to decametric reactors, micro-columns) to the metric scale (columns and tanks) in the experimental facility.

Experimenting to understand, experimenting to take action

Building on its achievements to date, the BRGM is now boosting its experimentation policy. This is one of the aims of the PIVOTS programme (platforms for innovation, development and optimisation of environmental technologies), a coordinated series of six platforms that involve public and private organisations in the Centre-Val de Loire Region in synergy-building through cross-cooperation.

The PIVOTS programme will enable the BRGM to strengthen its experimentation capacities, in particular through PRIME (platform on remediation and innovation in environmental metrology), which focuses on water, soil and polluted sediment metrology, understanding transfer processes and ecotechnology development for environmental remediation. PRIME will be located in the BRGM's experimental facility, which is to be upgraded with new metric and even multi-metric equipment. A multi-metric pilot (PPM), the only one of its kind in France, is to be designed and installed.

PRIME will also have capacities to host projects developed by public and private partners. The platform will enable new scientific concepts to be developed in conjunction with operational technical innovations to support economic players, under the same banner: "Experimenting to understand, experimenting to take action".

2 000 M^2

SURFACE AREA OF THE BRGM'S EXPERIMENTAL FACILITY

An experimental set-up with metric-scale instrumentation. © BRGM - PATRICK DESBORDES

Experiment on the resuspension of metals in harbour sediment. © LAURENT MIGNAUX – MEDDE

DEVELOPMENT AND ADMINISTRATION OF INFORMATION SYSTEMS
ARCHITECTURE, MAINTENANCE, PROCESSING AND COMPUTER INFRASTRUCTURE SECURITY
COMPUTING, 3D DISPLAYS AND VIRTUAL REALITY
INTEROPERABILITY AND WEB DISTRIBUTION

"With Big Data technologies, Earth observation data can now be widely used."

INFORMATION SYSTEMS

3 QUESTIONS TO

Jean-Marc TROUILLARD • Director, Information Systems Division

The Internet of Things (IoT), big data, the semantic web: how is the BRGM making use of these new digital technologies?

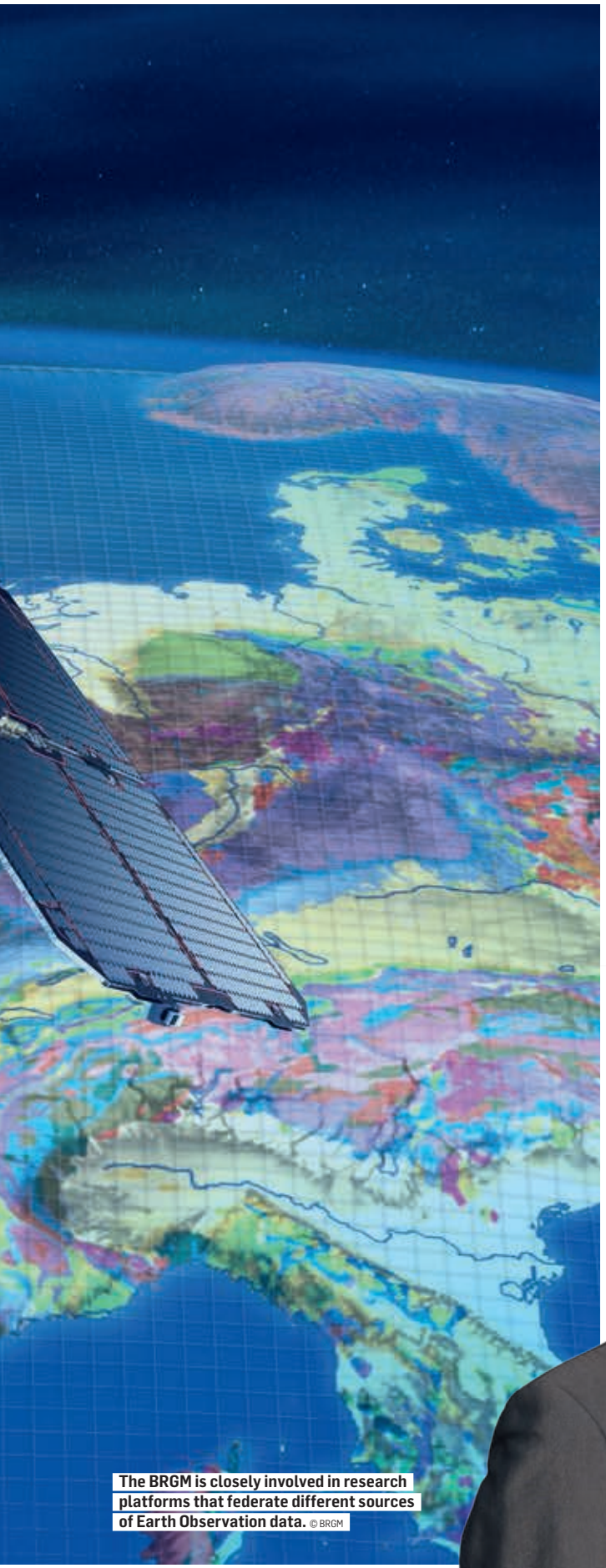
To make the most of these new technologies, they need to be used as part of a functional research and industry "ecosystem". The BRGM is therefore developing partnerships with different industries. For example, we are working with Atos on the SparkIndata programme, which was selected under a call for projects on Cloud Computing & Big Data. SparkIndata, the first digital platform federating different sources of Earth observation data, is contributing to the emergence of a rich "ecosystem" of new uses and services (in agriculture, urban planning, security, climate, health, etc.). We are also cooperating with Intel on processing earthquake simulation data.

Are you continuing your contributions to major research platforms?

Yes, we are very much involved in European platforms. For example, we have a strong Information Technology position in EPOS, the European Plate Observing System, an EU research infrastructure for observing and understanding internal Earth dynamics and telluric risks.

In the field of digital transformation, what is the main thrust of the BRGM's SI policy?

I should first mention an important event in 2015, when we successfully launched production of ERP Opale, in which a major feature is the offer of web-enabled services for users of the package. But the major undertaking on which we have embarked is digital transformation, with a redefinition of our strategy and its implementation in transformation projects, all of which will be centred on innovation and user needs, with contributions from each of our core areas of competence. And the BRGM is ahead of the field in this area!



The BRGM is closely involved in research platforms that federate different sources of Earth Observation data. © BRGM

HIGHLIGHTS

Big Data to develop HUB'EAU ③

The French Water Information System (SIE) collects and distributes technical data on water and aquatic environments. Although the data are available, using them is complex. Making water data more easily deliverable is the aim of HUB'EAU, whose design involves the use of breakthrough technologies such as Big Data.

National water sampling databank ②

Data and information on quantitative water sampling are now available on line. The national water sampling databank (BNPE) went online on 27 January 2015 through its data distribution site, to provide continuous access to quantitative water sampling results that can be used to support assessments of constraints on water resources.

⊕ ***www.bnpe.eaufrance.fr***

Earthquake simulations now 1000 times faster ①

The BRGM and Intel France undertook a joint scientific project on improving predictions of earth movements thanks to high-performance computing architecture, where the aim was to speed up earthquake simulations. By optimising the EFISPEC3D computing code, developed to handle complex three-dimensional geological environments to predict seismic hazards locally, the research team accelerated simulation times by a factor of 900 across 1024 computer cores, thus producing a realistic simulation of a seismic risk in just 10 hours, as opposed to 9000 hours with a single core.

BRGM leads an EPOS Work Package

The BRGM is leading the "Geological Information and Modelling" work package for EPOS (European Plate Observing System), an EU-wide infrastructure for observations and studies of the Earth system and its different compartments (geosphere, hydrosphere, atmosphere and biosphere).

BRGM-Atos partnership and initial studies ④

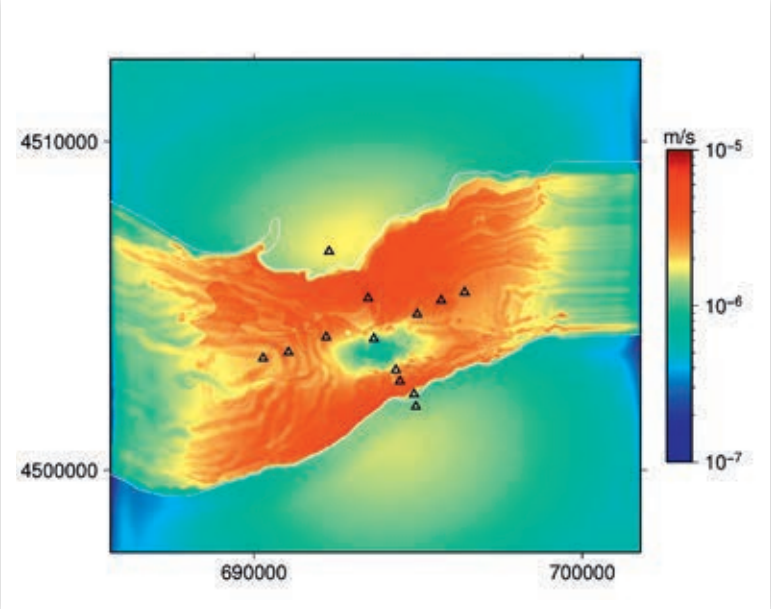
The BRGM and Atos have signed a partnership agreement for the joint production of innovative digital services for the geoscience, environment and construction sectors, in the wake of their fruitful SparkIndata partnership, which contributed to the emergence of a rich "ecosystem" of uses and services by establishing the first platform federating different sources of Earth Observation data. Aims of the new partnership: intelligent sensors and data collection, cross-referencing and mass processing of information, analyses and data products, agility, upgradability, security and data protection.

The OPALE package goes on line

Launched in March 2015, the OPALE package, a new management information system, incorporates all of the BRGM's operational scientific and functional processes, from analyses of the acquisition, processing and distribution cycles of administrative and management data to computer infrastructure and servers.

①

Maximum intensity of the horizontal movement of soil particles during an earthquake of magnitude Mw = 2.6 (test case I2b_FLAT from the EUROSEISTEST benchmark). Coverage: approx. 15 x 15 km. © BRGM

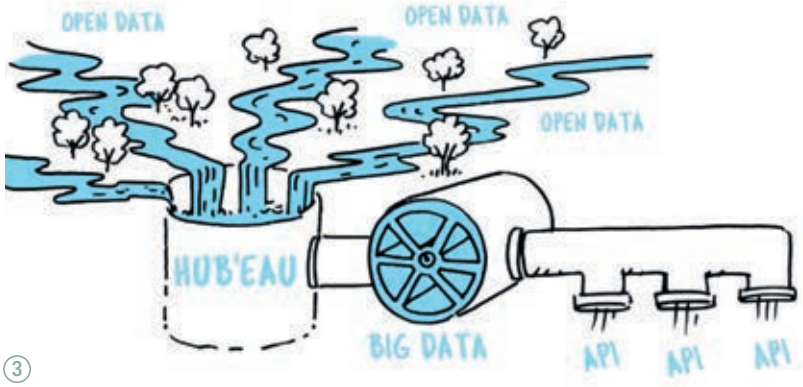


②

Reconnaissance and geochemical background measurements at a spring on an unstable slope of the Montagne Pelée (Martinique, 2012).

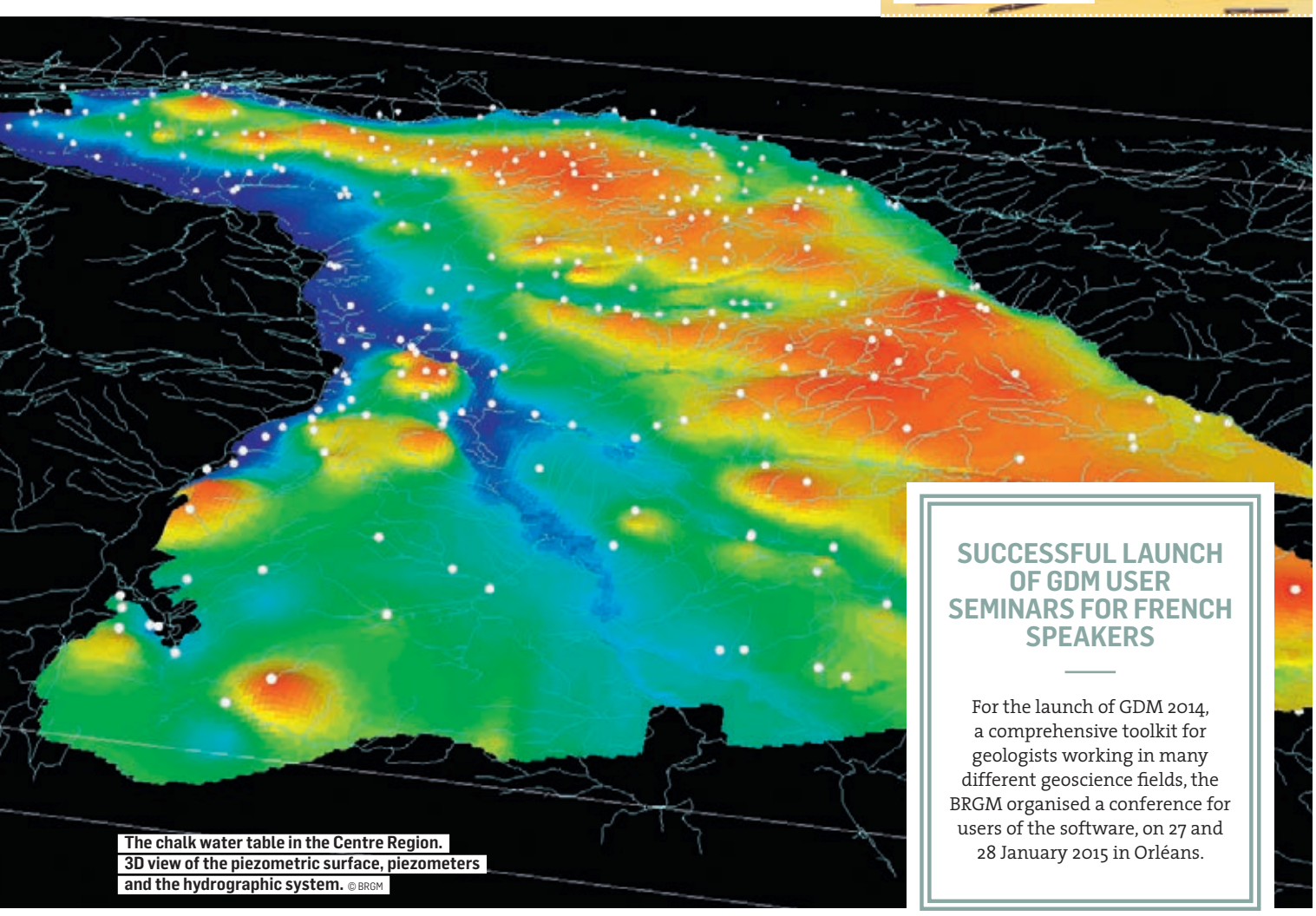
© BRGM - MATHILDE SENERGUES

OPALE



3 Hub'Eau: a digital hub to simplify access to water data. © BRGM

4 Vincent Laflèche (BRGM) and Thierry Siouffi (Atos) sign a partnership agreement on 6 November 2015. © ATOS



The chalk water table in the Centre Region. 3D view of the piezometric surface, piezometers and the hydrographic system. © BRGM

SUCCESSFUL LAUNCH OF GDM USER SEMINARS FOR FRENCH SPEAKERS

For the launch of GDM 2014, a comprehensive toolkit for geologists working in many different geoscience fields, the BRGM organised a conference for users of the software, on 27 and 28 January 2015 in Orléans.

New standards issued for water information

Sylvain GRELLET
Scientific programme manager

François ROBIDA
Deputy Director,
Information Systems Division

Standardisation is essential in the geosciences to facilitate exchanges and sharing of information between experts. This is particularly important in the case of water information, which involves many different players from different organisations. The process has been boosted by the "Orléans Resolution" and its adoption of a new family of standards.

To geoscience researchers, but also to the wider community of operational players in the water sector for example, adopting and developing data exchange standards is crucial. Professionals in the water sector not only have very different functions, but are also widely scattered across different agencies (national water agencies, international commissions, research organisations, etc.). It is essential for these different organisations to be able to exchange data easily, especially on hydrology and meteorology. But this demands common protocols and effective system and data interoperability - and there is a lot of work to be done!

Water data: too much time spent locating the right information

Work on standardising international exchanges of information in the geosciences, in which the BRGM has a leading role, began some time ago. And yet, there are still many problems with exchanging water data and system interoperability: when the data presented and exchanged are too heterogeneous, consistency is a problem. From one area of competence to another, it has been estimated that people spend roughly 30% of their time just to locate and understand the information! This obviously causes considerable complications in specific transboundary cases where organisations in different countries have to share information, for example to predict floods and water table levels.

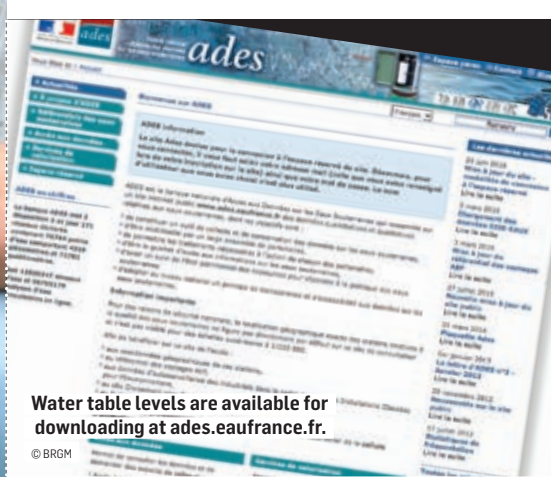
The "Orléans Resolution": a significant step forward

2015 saw a significant step forward on the standardisation of water data. The "Orléans Resolution" was the highlight of the Open Geospatial Consortium's 6th "Hydrology Domain Working Group" (HDWG) workshop, organised by the BRGM on 20 and 24 September 2015. The Open Geospatial Consortium (OGC) issues international and open standards for geographical information and data processing. These standards are used, for example, in online applications such as Google Earth, Google Maps and InfoTerre, and recommended by the INSPIRE Directive and even the Obama administration.

The BRGM working group during the 6th "Hydrology Domain" workshop in September 2015. © BRGM

Taking piezometric measurements.
© BRGM

6 DATA EXCHANGE STANDARDS CONSOLIDATED INTO ONE FAMILY



Water table levels are available for downloading at ades.eaufrance.fr.
© BRGM

The annual HDWG workshop is an opportunity for international experts from different backgrounds to work together, exchange experiences, discuss results and advances and develop appropriate standards for exchanges of water data and modelling. The "*Orléans Resolution*" concludes as follows: "*The hydrology committee of the WMO (World Meteorological Organisation) recognises that the standards prepared or incubated by the Hydro Domain Working Group have reached a sufficient stage of maturity to be applied to the WHOS information system of the WMO*".

The HDWG itself has recommended the creation of an online portal for the WMO's hydro-information system to facilitate access to the water data services provided by national hydrological agencies, in line with OGC standards.

The API family of standards

In practice, a family of six standards was adopted, for hydrological measurement series, hydrogeological resources, rating curves, water quality, exchanges of observations *via* API and Internet queries. An Application Programming Interface (API) is a standardised set of semantic and associated tools that enable developers to create software through simple and direct uses of other software services. The BRGM's teams played a central part in developing the first two standards in the family: co-writing the data models, running test cases and iterative tests with real data, etc. The BRGM thus established a data structure describing the rules for structuring the information, and deployed implementation tools in XML. These standards for water data are likely to be extended to environmental data.

"Standardisation is a major issue in specific transboundary cases where organisations in different countries have to share information, for example to predict floods or water table levels"

Courses to match changing economic, environmental and social needs

The BRGM's training branch, "BRGM Formation", was attached to the BRGM's Development Division in 2015. As a strategic activity within the business relations unit, its role is to boost the market for BRGM training by developing courses to match the needs of a changing society.

Established in 1994, the BRGM's training branch works to transfer the BRGM's scientific and technical know-how to socio-economic activity sectors. It runs courses catering for the continuing professional training needs of all organisations involved in soil and subsoil management, from public spatial planning, resource management and environmental protection agencies to engineers, consultancies, site managers and professionals in the field.

Adaptability and flexibility

"Courses may be chosen from our catalogue but we also offer tailor-made training covering all of our topic areas: natural risks and coastal protection, polluted sites and soils and waste management, as well as geology, hydrogeology, geothermal applications and mineral resources", says Charlotte Vinchon, manager of the BRGM training branch.

In 2015, the catalogue listed 83 courses and 60 sessions were organised, either in-house or inter-company. Demand was especially high for training on groundwater and polluted sites and soils, as well as for our course on low-temperature geothermal borehole drilling, which is particularly important for professionals applying for "RGE" environmental certification. These courses are supervised by BRGM engineers, researchers and trainers, with external competences also brought in if required.

"2015 saw increasing demand for in-house courses", explains C. Vinchon. *"In many cases, these were adapted from courses listed in the catalogue to cover a specific case of interest to the client, or entirely new courses built up from several of the BRGM's areas of competence. For example, we developed a basic geology training course for suppliers of energy carrier equipment, and a special session on hydrogeological modelling to address an actual case that the company had to deal with. Our policy of adapting training to needs applies at every level, from the creation in 2015 of a course on geological risks and hazards for an insurance company to the drilling course for "RGE" certification, where the training methods were adapted to suit professionals working in the field."*

An "ambassador's" role

"Training has a strategic role at the BRGM", says C. Vinchon. *"Many of our courses, especially those organised in-house, have an «ambassador's" function as they are often the prelude to a relationship with the client that will lead to operational applications of our scientific knowledge and know-how."*

In 2015, a market survey was launched and a working group set up to define the role of our training branch more precisely, both within the BRGM and as a contributor to other training organisations, and to assess the relevance of the courses currently on offer. Aim: dynamic adaptation of our courses to current and future economic, social and environmental needs for spatial planning and soil and subsoil management for sustainable development.

To achieve this, we will also be strengthening partnerships - now being formalised - with prescriptive agencies such as the ONEMA or ADEME, to adapt - the BRGM's watchword! - to the new provisions of the recent vocational training reform.

"The BRGM training branch needs to strengthen its role as a BRGM ambassador to economic players."

Charlotte VINCHON
Manager, BRGM training

+110%

GROWTH IN TURNOVER FOR TAILOR-MADE TRAINING COURSES SINCE 2011 (+ 35% FOR CATALOGUE COURSES)

ENAG

A NEW VOCATIONAL DEGREE COURSE FOR DEPOLLUTION TECHNICIANS

In 2015, the ENAG launched a vocational degree course for depollution technicians, thus broadening its training offer in this area. Seven years after ENAG was set up by the BRGM as a specialised training organisation, it will be changing its name to "BRGM Campus".

The new name reflects the school's vocation as a training organisation for professionals working in the field, with courses closely tailored to the needs of industry and society in the areas of soil, subsoil and resource management.

Since 2009, ENAG, the BRGM's School of Applied Geosciences, directed by Dominique Guyonnet, has trained over a hundred students at Orléans, who are now working for mining companies and engineering consultancies or working on PhD theses. The school now offers two different diploma courses. The first, which is open to students in their first Master's year or having completed the second year, to engineering school graduates and to employees in the mining sector, is entitled "Enag-2GR: Geology and Sustainable Mineral Resource Management". As one of the four Master's courses in "Earth sciences, sciences of the Universe and Environmental sciences" (STUE) offered by the University of Orléans, it prepares students for a Master's degree complying with the European "Bachelor-Master-Doctorate" system.

Students on the new vocational degree course for depollution technicians: Depollution of contaminated sites and soils: sampling techniques for potentially polluted sediments. © BRGM

In 2015, fifteen students followed this course, which places a strong emphasis on field training in geology for mineral exploration, the mining environment and post-mining. Some modules may be taken by up to thirty students, some from other STUE courses at the University of Orléans.

A highlight in 2015 was the launch, at the Paris-Est University of Marne-la-Vallée, of a new vocational degree for depollution technicians, with an initial intake of 9 students and strong participation from depollution professionals (UPDS and UCIE professional unions). Students taking this block release course work for a month in the BRGM's premises in Orléans, using the platform set up specifically for the course module on water, soil and gas sampling in polluted soils and sites.

Discussions are continuing with the Ministry of Education and Research with a view to expanding ENAG's scope of activity under the European LMD system. For example, ENAG now takes on PhD theses submitted by the BRGM, with support from the Development Division. And to emphasise the BRGM's position as provider of specialised training content in higher education, the ENAG school now has a new name: BRGM Campus.

Dominique GUYONNET
ENAG Director

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THE CHAIRMAN OF THE BRGM

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- Geology and mapping of bedrock resources
- Georesources observatory and economics

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- Deep and near-surface geothermal resources
- Geothermal energy and systems development

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- Gravity-related instability and slope and soil erosion risks
- Coastal risks and climate change
- Subsoil storage and operational risks
- Sinkhole risks, subsoil planning and imagery

Mine Safety and Risk Prevention
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- Programming and Methods Unit

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- Water economics and new water resources
- Environmental biogeochemistry and water quality
- Waste, raw materials and recycling
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Jean-Marc TROUILLARD

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- IT administration and operation
- Management information systems and assistance

Scientific Information and Digital Technologies
- Organisation and distribution of information
- Technological applications and expertise

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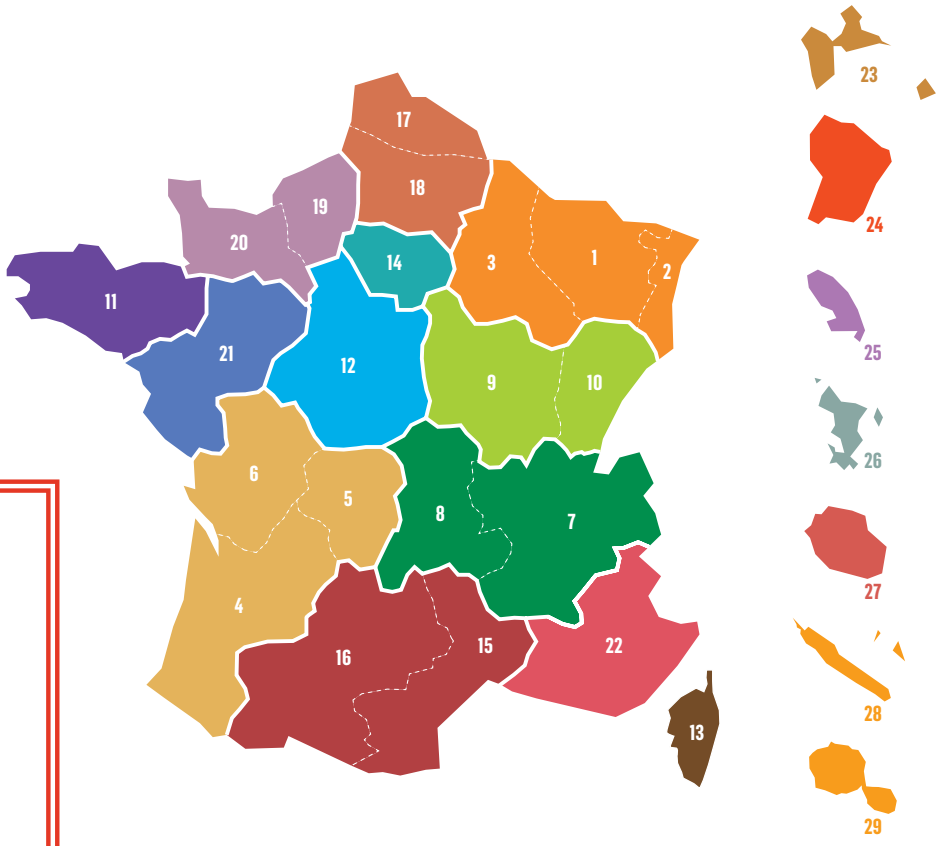
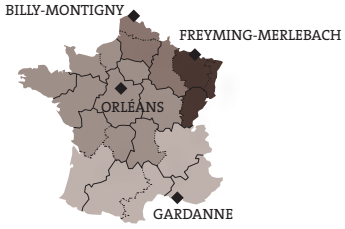
Stéphane ROY
- Inter-regional divisions: North-East, Centre-West, South-West, Centre-East, Mediterranean, Atlantic, Indian Ocean
- Overseas France agencies: New Caledonia, French Polynesia

REGIONAL NETWORK





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Mid-term assessment: a pivotal year

2015 was a pivotal year for the BRGM as it entered into the third year of its current performance contract with the State. Since 2013, when the contract came into force, the initial targets and indicators have been revised for greater clarity and concision. With the ongoing reorganisation of its management structure, the BRGM's governance system has become increasingly dynamic.

In 2015, the 5-year contract continued to demonstrate its effectiveness. The 2015 mid-term report highlights numerous positive results achieved since our activities were reorganised in accordance with our role at the hub of the geosciences: some projects and indicators are even ahead of schedule. The BRGM continued its efforts towards excellence in its scientific output and broad dissemination of its geoscientific knowledge. The BRGM is committed for five years, up to 2017, to the goals set out in its current performance contract with the State, which sets out a more closely targeted roadmap than the previous one, clarifying the BRGM's key roles and strategic goals. These goals are directly linked to the geosciences, the strategic partnerships to be established, the scientific quality of BRGM output, its input to public policy-making and its support to socio-economic players, with work programmes built up around excellence, interactiveness, knowledge transfer and expertise.

A new context

In anticipation of COP21 at the end of the year, 2015 saw the BRGM moving into a new overall context and strengthening its involvement in environmental and energy transition issues. The BRGM took part in several important events concerning climate change, such as those organised by the Ministry for Research and major players in French research. It also took part in programmes piloted by the ANR (French national research agency), addressing the following topics in particular: "low-energy resource management and climate change adaptation", "clean, safe and efficient energy" and "boosting the revival of industry", as well as topics addressed by the EU H2020 programme on "climate, resource efficiency and raw materials" challenges.

The BRGM also implemented an active partnership-building policy, signing numerous agreements with major groups such as Total, EDF, Veolia and Atos, while also, as a Carnot Institute, strengthening its efforts towards SMEs. In line with site management policy and thanks to its regional network across mainland and overseas France, the BRGM continued to develop its work in topic areas that address regional priorities, such as the French Geological Reference Platform (RGF programme), environmental metrology and local vulnerability assessments (coastal risks, coastline change, urban geology and island areas). Internationally, the BRGM continued its activities focusing on geoscience support to different countries (South America, Middle East and Africa).

With the territorial reform in France, which redivided mainland France into thirteen administrative regions, the BRGM conducted internal discussions on its organisational structure across France. Finally, with the continuation of the organisational overhaul piloted by its internal governance bodies, 2015 was a pivotal year for the BRGM in specific areas, with roadmaps drawn up, its scientific functions reformed and greater responsibilities delegated to its operational divisions as well as to all those involved in the BRGM's work, in order to enhance its adaptability to the issues at stake today.

Five goals over five years

2015 saw particular efforts towards the five goals set out in the performance contract, with several activities already ahead of the 5-year targets.

A landslip at Sauvat (Massif Central, S France, 2014). © BRGM

"With the continuation of the organisational overhaul piloted by its internal governance bodies, the BRGM continued its efforts towards excellence in its scientific output and wide dissemination of its geoscientific knowledge."

Moussa HOUMMADY
Delegate for strategy, forward studies and partnerships,
Strategy and Research Division

PERFORMANCE CONTRACT

GOAL 1

ENSURE EXCELLENCE IN SCIENTIFIC OUTPUT AND DEVELOP PARTNERSHIPS IN RESPONSE TO THE CHALLENGES OF SUSTAINABILITY AND GLOBAL CHANGE

Overall, our targets have been achieved and sometimes exceeded. Highlights include the number of BRGM publications in international reference journals and its share of overall French scientific output, i.e. 110 publications for a target of 90. The BRGM is also ahead of the targets set for "guest speakers" and "sessions chaired" in national and international conferences, with 70 in 2015 as against the target of 10 in the performance contract. The number and share of co-publications with partners in EU member countries stands at 48, already 25% ahead of target. Finally, the number of project contracts with French higher education and/or research organisations is slightly above the target figure.

INDICATORS	BASELINE *(reference year)*	2015	TARGET FOR 2017
1 / Number of BRGM international reference publications and share of French scientific output - (LOLF)	176 (2011) *%: to be confirmed**	**191** *(178 > 2014)*	**200** *%: to be confirmed**
1.1/ Including number and share of international co-publications with French research institutions (LOLF)	80 (2011) *%: to be confirmed**	**110**	**90** *%: to be confirmed**
2/ Average number of citations of BRGM publications within 2 years (scientific recognition expressed through the 2-year science citation index) - (LOLF)	4.74 (2011)	**1.42****	**5**
3/ Number of "guest speakers" and "sessions chaired" in national and international conferences	10 (2012)	**70**	**15**
4/Number of officially registered theses supervised and co-supervised by calendar year	57 (2012)	**61**	**60**
5/ Number and share as participant in ongoing projects financed under EU framework programmes (FPRD) - (LOLF)	29 (2012) *%: to be confirmed**	**27**	**30** *%: to be confirmed**
6/ Number and share as coordinator of ongoing EU-financed projects (FPRD) - (LOLF)	3 (2012) *10%*	**1** *4%*	**3** *10%*
7/ Number and share of co-publications with EU partners - (LOLF)	30 (2011) *17%*	**48** *25%*	**40** *20%*
8/ Number of full-time job equivalents involved in joint research and service organisations or recognised research teams (UMR, UMS, etc.)	8.4 (2012)	**8**	**12**
9/ Number of projects under contract with French higher education and/or research establishments	140 (2012)	**146**	**140**
10/ Percentage of geological areas covered (including overseas France) by a layer of integrated 3D geoscientific data compared to the areas envisaged by the RGF steering committee	NA	**40 %**	**80%**
11/ Share of scientific investment (movables and immovables) as a ratio of internal financing capacity	48,5% (2012) *Provisional figure*	**26.7% *****	**60%**
Milestone: opening in September 2014 of a Master's specialist diploma course in mineral resources	NA	**Achieved**	-
12/ Number of international scientific partnership agreements	23 (2012)	**24**	**30**

** Figure not yet available for 2015*
*** Change in calculation method*
****Result due to exceptional circumstances: high CAF due to reserves and renewal of VAT rate for post-mining (one-off non-recurrent impact)*

Following the spring thaw, theMotzfeldt rare earths deposit will be mined and its fjord developed for harbour facilities (Gardar Province, Greenland, 2013). © BRGM - JOHANN TUDURI

GOAL 2

MOBILISE AND DISSEMINATE SCIENTIFIC KNOWLEDGE AND BUILD UP EXPERTISE TO SUPPORT PUBLIC POLICY DEVELOPMENT

The FP7 IMAGE project reached mid-term in 2015 and several research projects on deep geothermal layers in different contexts were launched (AMI Ademe: FONGEOSEC, Géodénergies: REFLET and TEMPERER, H2020: DEEPEGS, ANR: CANTARE Alsace), as well as a review of surveillance operations in several basins (e.g. Decazeville, Burgundy, potash basin).

INDICATORS	BASELINE *(reference year)*	2015	TARGET FOR 2017
13/ Number of reports contributing to the development of regional policies on aggregate, construction materials and industrial minerals	15 (2012)	3	17
Milestone: operational implementation of the Mineralinfo portal as part of the mineral raw materials observatory (2nd semester 2014)	NA	Achieved	-
14/ Impact of online data management and distribution			
14.1/ Number of databases and georeferenced information layers	220 (2011)	273	250
14.2/ Number of services made available on line	223 (2011)	254	270
14.3/ Number of InfoTerre consultations	421 690 (2011)	684 036	520 000
15/ Number of expert reports published under formal public commissions - (LOLF)	606* (2012)	488	400*
16/ Number of regional (or other local) atlases, mainly for project owners and drilling companies, showing aquifer resources, vulnerability of subsoil zones targeted by very low enthalpy geothermal operations and corresponding administrative zoning	0	0**	20
17/ Overall budget for BRGM work on exploration, characterisation and modelling of deep geothermal resources (2013-2017)	1.37 M€ (2011)	1.57 M€	6 M€
18/ Number of workings and facilities monitored and managed by the BRGM for post-mining purposes	1 861 *(2012 figure from the 3 Ministerial Orders of 2 May 2012 setting out the list of facilities managed by the BRGM)*	1 831	*According to Ministerial Orders setting out facilities under BRGM management*
Milestone: Management flow chart established for the national public services steering committee (CNOSP) (end 2013)	NA	Achieved	-

** Request for adjustment of the threshold and target figures for consistency, in view of actual figures*
*** Several atlases in production*

GOAL 3

FORGE A PROACTIVE POLICY GEARED TO INNOVATION AND THE DEVELOPMENT AND TRANSFER OF APPLICATIONS TO SUPPORT ECONOMIC ACTIVITIES

2015 again saw a large increase in the numbers of patents claimed and software registered.

INDICATORS	BASELINE *(reference year)*	2015	TARGET FOR 2017
19/ Share of research contracts with French or foreign public or private companies compared to total BRGM research resources - (LOLF)	4.7% (2012)	**3.91%**	6%
20/ Total number of people taking awareness training on protecting and communicating scientific results	20 (2012)	**34***	200
21/ Total number of patents and software applications registered (2013-2017) - (LOLF)	4 (2012)	**21**	20
22/ Effectiveness of development policy expressed as the ratio of "royalties, software and other licences" over "expenses associated with intellectual property protection" - (LOLF)	1.8 (2012)	**1.15**	2

** Internal restructuring and start of training in negotiation for engineers.*

A drone's eye view of the beach and cliff at Criel-sur-Mer: photogrammetry for coastal monitoring. © BRGM - THOMAS DEWEZ

GOAL 4

STRENGTHEN INTERNATIONAL ACTIVITIES TO INCREASE KNOW-HOW IN VARIED CONTEXTS

Of particular note here is the share of international turnover in total earnings (7.1%), especially for work on geology and mineral resources, which reached 4.8% towards the 2017 target of 5%.

INDICATORS	BASELINE *(reference year)*	2015	TARGET FOR 2017
23/ Share of international activities in total income	5% (2011)	**7.1%**	9%
23.1/ Including share for geology and mineral resources	2% (2011)	**4.8%**	5%
23.2/ Including share for MDGs (water, environment, geothermal energy, natural risks)	3% (2011)	**1.7%**	4%


Students on a field course in Congo Brazzaville. © BRGM

GOAL 5

ADAPT BRGM COMPETENCES AND PRACTICES TO SUPPORT SCIENTIFIC OUTPUT GEARED TO SUSTAINABLE DEVELOPMENT

Of particular note in 2015 is the continued drop in energy consumption: 11.2% compared to 2011, with a target reduction of 10% by 2017. Similarly, paper consumption dropped by 17.9 % compared to 2012, with a target reduction of 12 % by 2017. The number of photocopies in departments dropped by 22.8% compared to 2012, and by 29.6% in the central reprographics department.

INDICATORS	BASELINE *(reference year)*	2015	TARGET FOR 2017
24/ Reductions in energy and paper consumption			
24.1/ Energy consumption per full-time equivalent in all sites concerned	7 774 kWh / FTE (2011)	6 907 kWh	- 10%
24.2/ Paper consumption per full-time equivalent in all sites concerned	7 641 pages/FTE (2011) 8 252 pages/FTE (2012)*	6 779	- 5% - 12%, new target proposed *
25/ Percentage career planning interviews conducted with staff	41% (2011)	**	70%
26/ Percentage women managers	22% (2012)	29%	30%
27/ Coverage of priority risks (ratio of number of risks covered by action plan / number of priority risks identified)	NA	65%	70%
28/ Gross operating surplus	+6.3 M€ *(2012)*	10.1 M€ ***	6 M€

* *Change in baseline year due to change in perimeter and new goal proposed*
** *No career interviews in 2015 due to the reorganisation of the HR Division planned for that year*
*** *Result due to non adjustment to VAT in the grant for "post-mining operations"*

Results were positive for the BRGM but down for the Group as a whole

Consolidated operating income for the BRGM Group in 2015 stands at **159.72 M€**, down by 4.11 M€ (-2.5 %) compared to 2014 (163.83 M€). Operating expenses in 2015 amounted to 152.74 M€ as against 160.95 M€ in 2014, a drop of 80.21 M€ (-5.0%). The net consolidated result for the incorporated companies in 2015 stands at -2.48 M€, including the BRGM Group share of -2,86 M€ (and +0.39 M€ paid out to the IRIS minority shareholders). FY 2015 saw Géothermie Bouillante opening up its capital with a view to finding a new industrial and financial partner to contribute the necessary means for this subsidiary to develop its activities, given the sharp drop in nickel prices reflected in a substantial depreciation in the BRGM S.A. accounts, the positive balance for CFG Services and the start of the merger between SERGAP and SAGEOS.

Also to be noted is the continuation of BRGM S.A. activities on safety engineering and rehabilitation of the Group's former mining sites. Finally, IRIS Instruments had a profitable year, maintaining its turnover in a difficult and highly competitive context.

As in 2014, the BRGM EPIC contributed 87% of consolidated Group income in 2015, Géothermie Bouillante 6% and CFG Services and IRIS Instruments about 3% each.

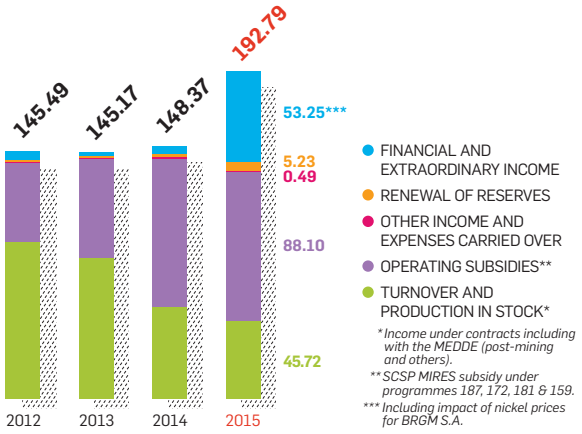
+7.81 M€

BRGM OPERATING PERFORMANCE 2015

139.55 M€
OPERATING INCOME 2015

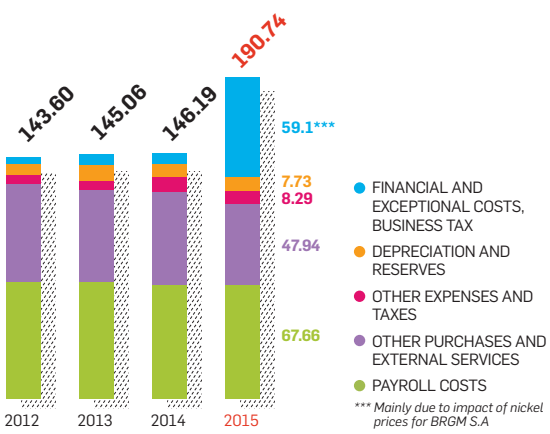
131.74 M€
OPERATING EXPENSES 2015

TOTAL INCOME 2012-2015



** Income under contracts including with the MEDDE (post-mining and others).*
*** SCSP MIRES subsidy under programmes 187, 172, 181 & 159.*
**** Including impact of nickel prices for BRGM S.A.*

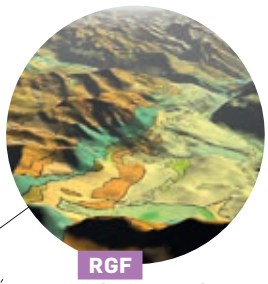
TOTAL EXPENSES 2012-2015



**** Mainly due to impact of nickel prices for BRGM S.A*

TURNOVER BY TOPIC AREA

POST-MINING
29.91 M€



RGF
18.14 M€

OTHER
4.59 M€

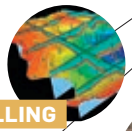
LABORATORIES AND EXPERIMENTATION
10.33 M€

134.15 M€
TOTAL TURNOVER

OBSERVATION NETWORKS
12.14 M€

GEOTHERMAL ENERGY
4.04 M€

INFORMATION SYSTEMS
8.79 M€



MODELLING
2.86 M€

WATER
6.29 M€

ECONOMIC STUDIES
2.02 M€

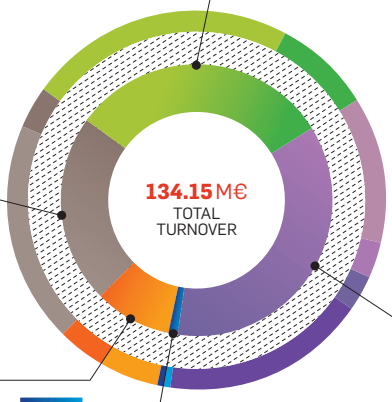
POLLUTED SOILS
12.78 M€

MINERAL RESOURCES
6.01 M€

RISKS
16.27 M€

TURNOVER BY KEY ROLE

EXECUTION OF THE 2015 BUDGET



SCIENTIFIC RESEARCH
41.90 M€

30.76 M€
SCSP (P187 then P172)
11.14 M€
Agreements

POST-MINING
29.91 M€

25.15 M€
(SCSP P181)
4.76 M€
Intervention

SUPPORT TO PUBLIC POLICY DEVELOPMENT
48.61 M€

16.78 M€
SCSP (P187 then P172)
4 M€
SCSP (P181)
4.11 M€
Agreements SCSP P181
23.71 M€
Other agreements

SERVICES
12.54 M€

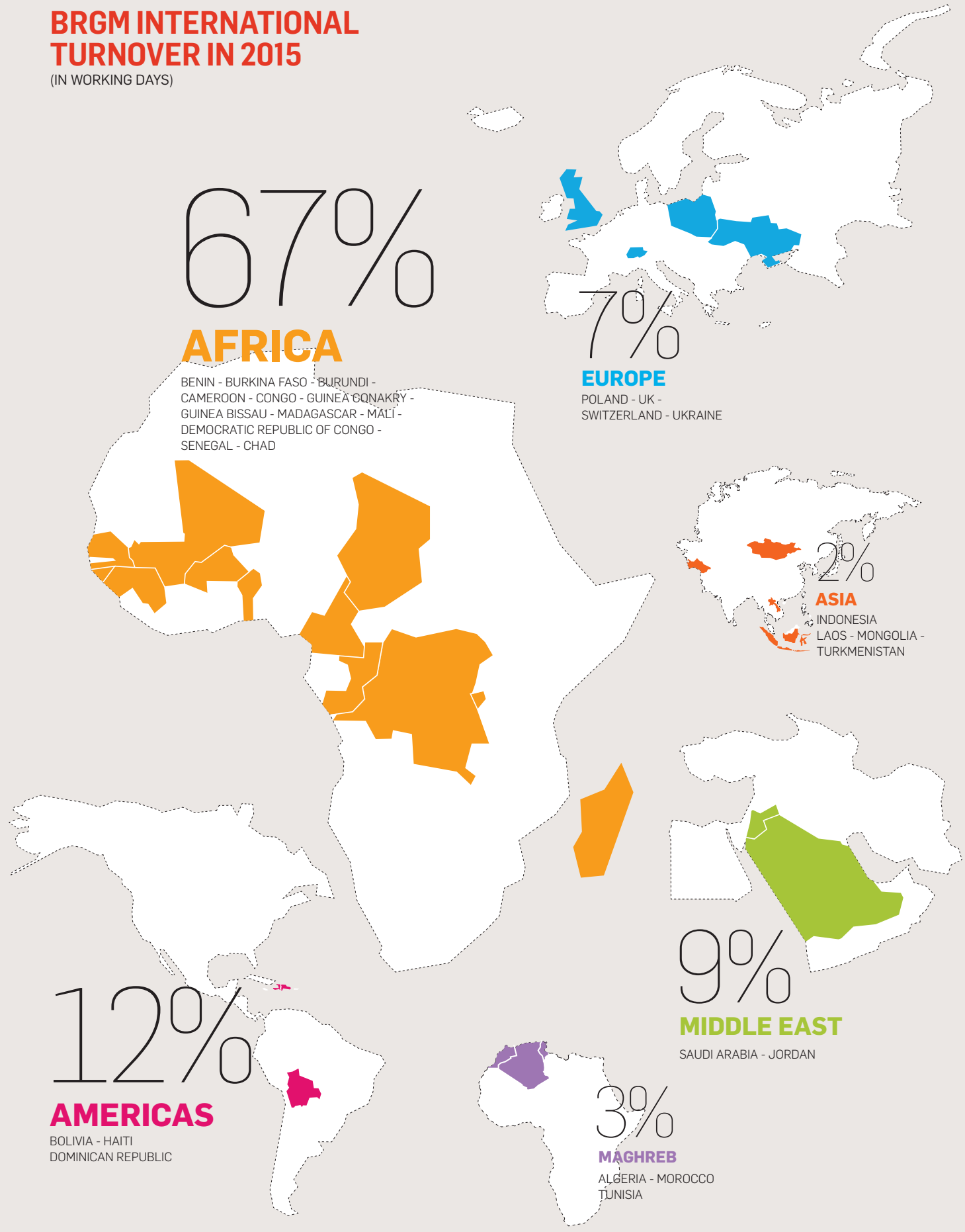
7 M€
INTERNATIONAL
5.54 M€
FRANCE

ENAG
1.19 M€

0.75 M€
SCSP
(P187 then P172)
0.44 M€
Agreements and contracts

BRGM INTERNATIONAL TURNOVER IN 2015

(IN WORKING DAYS)



67%

AFRICA

BENIN - BURKINA FASO - BURUNDI - CAMEROON - CONGO - GUINEA CONAKRY - GUINEA BISSAU - MADAGASCAR - MALI - DEMOCRATIC REPUBLIC OF CONGO - SENEGAL - CHAD

7%

EUROPE

POLAND - UK - SWITZERLAND - UKRAINE

2%

ASIA

INDONESIA
LAOS - MONGOLIA - TURKMENISTAN

9%

MIDDLE EAST

SAUDI ARABIA - JORDAN

12%

AMERICAS

BOLIVIA - HAITI
DOMINICAN REPUBLIC

3%

MAGHREB

ALGERIA - MOROCCO
TUNISIA

A positive result for the BRGM EPIC

The BRGM's total **operating income** for 2015 amounted to **139.55 M€**. Discounting reserves and expenses carried over, total income amounts to 134.15 M€, down by 7.8 M€ compared to 2014.

Operating expenses totalled **131.74 M€**, or 128.70 M€ after deducting reserves for depreciation and expenses carried over. With a 7.5 M€ drop in total external charges, the BRGM maintained its economic added value. Gross operating surplus amounted to 10.11 M€ as against 10.18 M€ in 2014. Under the terms of the current profit-sharing agreement for 2013-2015, this will produce an overall staff bonus of 1.77 M€.

Operating performance stands at +7.81 M€ as against +4.16 M€ in 2014. The financial result is negative at -5.44 M€ due to the impact of nickel-related projects at BRGM S.A. **The net result is positive at +2.05 M€.**

Along with five other public targeted research bodies (IRSTEA, CIRAD, IFREMER, INRA and IRD), the BRGM operates on behalf of the State under Programme 172 in the Organic Law on Public Accounts (LOLF). This programme, which is managed by the Interministerial Task Force for Research and Higher Education (MIRES), covers 11 activities, with the BRGM contributing to five of these in 2015. The BRGM also receives subsidies for public service expenditures (SCSP) under programme 181, for its post-mining activities in particular.

Income under contracts and agreements, 2012-2015

The drop in income compared to 2014 is mainly due to a lower turnover with Agencies and under the "sensitive facilities" project and the postponement of H2020 projects. Turnover from commercial and international cooperation activities increased despite the unfavourable international context (7.01 M€ as against 5.0 M€ in 2014). Turnover from post-mining projects dropped (-2.7 M€) due to postponements to 2016.

+2.05 M€

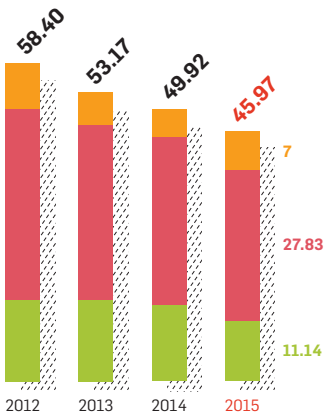
NET BRGM RESULT, FY 2015

Income under contracts for scientific research and public policy development support, 2013-2015 (in k€ excl. VAT):

PRODUCTION UNDER SR CONTRACTS	2013	2014	2015
European Union + ERDF	4718	3 609	2007
ANR + Carnot	3901	2 988	2897
Agencies other than ANR	12983	12724	14039
Local authorities	4934	5 597	4280
Ministries + State agencies	17356	15 910	12820
Companies	3264	4056	2925
TOTAL	**47156**	**44 884**	**38968**

INCOME UNDER CONTRACTS 2012-2015

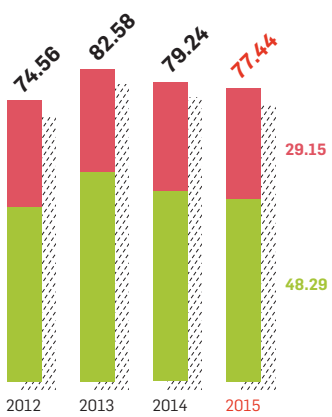
OTHER THAN POST-MINING AND ENAG IN MILLION €



INTERNATIONAL
SUPPORT TO PUBLIC POLICY DEVELOPMENT
SCIENTIFIC RESEARCH

GOVERNMENT GRANTS 2012-2015

IN MILLION €

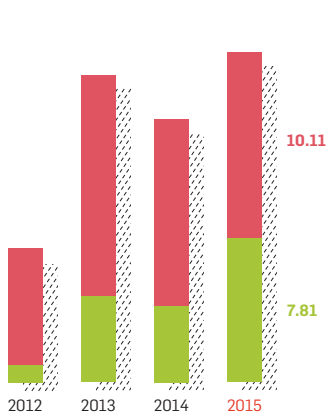


SCSP POST-MINING AND APP (PROGRAMME 181)
SCSP MIRES (PROGRAMMES 187 AND 172)

(SCSP: SUBSIDY FOR PUBLIC SERVICE EXPENSES)

OPERATING RESULTS 2012-2015

IN MILLION €



GROSS OPERATING SURPLUS AFTER PROFIT-SHARING
OPERATING RESULT

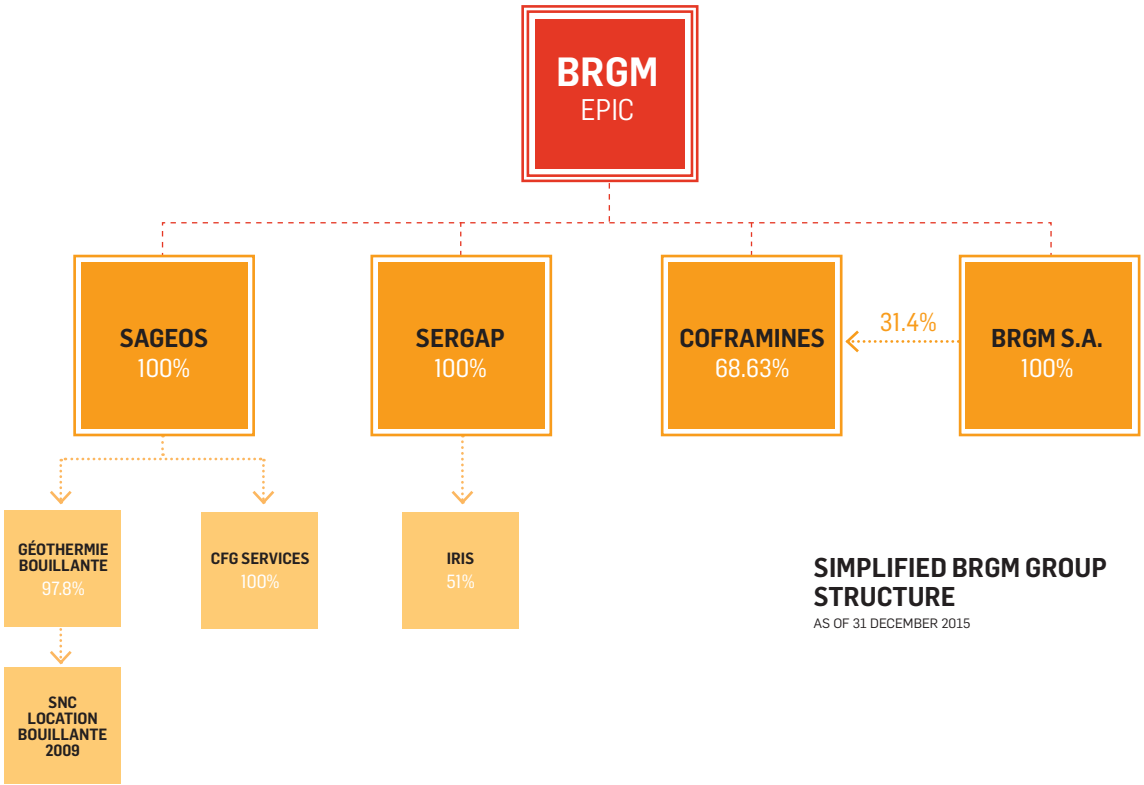
BRGM Group subsidiaries and holdings

The BRGM Group's subsidiaries and equity interests are held through four holding companies that correspond to three branches of activity, except for the BRGM's direct 1.5% equity interest in GEOGREEN, which is not included in the Group's consolidated accounts.

BRGM S.A. and COFRAMINES hold the BRGM Group's residual equity in the mining sector (dormant companies with no activities planned or companies under liquidation) and a minority share in ERAMET. BRGM S.A. has also held receivables from the *Société de Participation Minière du Sud Calédonien* (SPMSC) since 2005, when the BRGM Group transferred its share in the GORO project in New Caledonia to the SPMSC.

In the geothermal branch, BRGM equity in CFG Services, a geothermal engineering and energy provider, and in GÉOTHERMIE BOUILLANTE, which operates a geothermal energy plant in Guadeloupe, is entirely held through SAGEOS. The BRGM held 97.8% of GÉOTHERMIE BOUILLANTE equity at the end of 2015, with the remainder held by EDEV, an EDF subsidiary.

SERGAP has a 51% equity share in the geophysical instrumentation company IRIS Instruments.



SIMPLIFIED BRGM GROUP STRUCTURE
AS OF 31 DECEMBER 2015

Jean-Claude GUILLANEAU
Chairman, CFG Services

Chairman: **Jean-Claude Guillaneau**
Managing Director: **Éric Lasne**
Turnover: **5.56 M€**
BRGM holding: **100%**
Payroll: **31 employees**

For more information: ***www.cfgservices.fr***

CFG Services is currently active in three main market segments: geothermal energy for heat and power production, and the corrosion and industrial microbiology market. These markets have strong roots in France, but each also has an international dimension.

CFG Services works in four main areas, in France and internationally:

> Studies and expertise in the geothermal resources field: identification, uses and operations (heating networks, industrial processes, electricity production),
> design and project engineering and management for all low-energy and high-energy geothermal applications (including EGS),
> operational maintenance and monitoring,
> expert studies and sales of services and products in the fields of corrosion and industrial microbiology.

CFG's Technical Heat Uses Division (DTUC) is a service provider for:

> project management or new geothermal production projects or extensions to existing facilities,
> operational maintenance and monitoring in France and Switzerland,
> studies, engineering and compliance documentation,

2015 saw significant growth (+14 %) in project management turnover, thanks to a dynamic market for deep geothermal projects. Highlights in 2015 include the completion of three new doublets for the Engie Group in Rosny-sous-Bois, Ivry-sur-Seine and Bailly-Romainvilliers (nature village) and one doublet for Bageops (a Dalkia subsidiary) at Bagneux.

Each new doublet provides heat for 8 000 to 10 000 housing units, avoiding 10 000 tonnes of CO_2 emissions per year.

In parallel, three facilities were entirely renovated or redesigned, at Tremblay-en-France (for a Dalkia-Idex group), Chevilly-Larue and L'Haÿ-les-Roses (Semhach) and Ris-Orangis (Coriance Group).

2015 also saw a significant innovation with the application of technological R&D work conducted by CFG Services in 2013 and 2014. The four doublets at Chevilly-Larue and L'Haÿ-les-Roses, which had become corroded since their installation in the 1980s, were successfully rehabilitated thanks to the use of glass-fibre tubing. This unprecedented technical achievement in geothermal energy in France attracted significant media attention at a press conference organised on 28 August 2015 for the 30th anniversary of CFG Services, attended by 21 different media.

These achievements have confirmed the position of CFG Services as France's leading company in deep geothermal engineering and project management (70% market share).

Despite a 20% drop in turnover compared to 2014, operational maintenance and monitoring activities continued at a sustained pace similar to 2013. These activities concerned 23 facilities in France (20 in Greater Paris and 3 in Aquitaine) and one in Switzerland.

Sales of electromagnetic scanner diagraphs (used to inspect the condition of tubes - see 2014 Annual Report) were not up to expectations in 2015. However, this technique has proved its value and is attracting interest from drilling professionals and the government agency in charge of drilling inspections, which is considering making it compulsory in some contexts.

Turnover from compliance studies and filing (for exclusive permits for prospecting and exploratory work) was also down in 2015 compared to previous years. The decline in this market sector is largely due to the drop in fossil fuel prices, which has affected the competitiveness of geothermal energy for heating networks. After investing heavily for some time in geothermal energy and heating networks, France's leading energy companies need to raise investment capital for new projects.

SUBSIDIARIES AND HOLDINGS

In 2015, CFG Services also contributed to BRGM research partnerships. Possibilities for secondary upgrading of geothermal doublets for CO_2 reinjection were investigated under the ANR "CO2Dissolved" project. Under the "Recomfor" project, in cooperation with the Georesources Division's geothermal energy department, possibilities were identified for the acquisition of geological and hydrogeological data to characterise little-known geothermal reservoirs that have to be drilled through to reach the Dogger aquifer in the Paris basin.

The company's power production activities and expert studies on industrial corrosion are handled by its Electricity and Corrosion Technical Division (DTEC).

At the Bouillante site, CFG Services continued to monitor the behaviour of the geothermal reservoir for its sister company, Géothermie Bouillante. A hydraulic and thermal model of the Bouillante reservoir was developed in cooperation with the BRGM. The simulations run with "Tough 2", a widely used computing code in high-temperature geothermal engineering, aimed to gain a better understanding of the thermal and hydraulic behaviour of a reservoir affected by production and partial reinjection of cold fluids. To supply additional calibration data, pressure and temperature profiles were produced for the BO-5 and BO-6 wells.

Installing glass fibre tubing during rehabilitation of the Chevilly-Larue doublet. © BRGM

Studies of the Masigit geothermal field in Indonesia, which began in 2014, did not reveal any high-temperature geothermal resources despite the field's proximity to the Kamojang field (200 MWe installed power). The studies were halted in agreement with the Indonesian partner, Pertamina Geothermal (PGE), but may be restarted under a different form to investigate possibilities for using the medium-energy resources that were identified.

In Alsace, the Electricité de Strasbourg (ES) CHP project was launched with the completion of project studies on subsoil workings. The aim is to install a geothermal doublet (2 wells some 3 300 in length) to reach the geothermal reservoir lying at the interface between the granite bedrock and the Rhine Graben sediment layer. CFG Services is handling the engineering studies for the two boreholes, which will be drilled to great depths through fractured and permeable zones that are favourable to high-temperature flows (estimated at 180°C).

One disappointment in 2015 was the abandon of a project in Dominica. The Dominican government's call for technical assistance tenders, notified to the Franco-Italian CFG Services-Electroconsult Group by the French Development Agency (AFD) in April 2015, was found not to be applicable and no contract was signed.

In the field of microbiology and corrosion expertise, CFG Services continued its activities for ANDRA. As a long-standing player in experimentation in this field, CFG Services was commissioned to undertake a major bibliographic synthesis by ANDRA's counterpart in Switzerland, the Etablissement du Mont Terri.

TOTAL, the licence-holder and main CFG Services client for Labège kits, requested a significant effort in 2015 on aging and quality controls for these culture mediums produced by CFG Services.

Production dropped sharply in 2015 compared to 2014, a particularly active year. The drop in oil prices had a negative impact on purchases by major oil companies, which were postponed or reduced for cost-saving reasons.

The net profit shown in the 2015 balance sheet nevertheless confirms that the company's repositioning effort on its traditional engineering and maintenance markets has been a success. High levels of activity were maintained by the company's teams of engineers and technicians, whose know-how and experience on these markets is now firmly established. The multi-year effort to control external expenditures and optimise project management contributed to the company's satisfactory results for FY 2015.

Chairman: **François Démarcq**
Deputy Managing Director: **Didier Gauthier**
Turnover: **9.9 M€**
SAGEOS holding (BRGM Group): **97.8%**
EDEV holding (EDF Group): **2.2%**
Payroll: **17 full-time employees on site**

More information at:
www.geothermie-perspectives.fr

François DÉMARCQ
Chairman, Géothermie Bouillante S.A.

Géothermie Bouillante is developing electricity production from geothermal resources in Guadeloupe and the Caribbean region.

The Bouillante plant is the main electricity producer in Guadeloupe's Basse-Terre area, contributing about 5% of the island's electricity supplies in 2015.

The main events at the plant in 2015 were:

> steam availability was generally lower than anticipated despite raising the pressure limit at the head of the reservoir;
> two major maintenance operations on n°4 rotor wheel on the GTA B2 unit;
> operations maintained at an acceptable level overall, as shown by overall electricity production of 83 GWh for the year and a turnover close to the budget forecast (9 890 k€ as against 10 430 k€).

Due to the low steam levels, constant efforts were made to optimise the use of the reservoir by balancing yields from each turbine against the pressure imposed at the head of the reservoir. The upshot was a limitation of possible production compared to the theoretical availability of the facilities, particularly in the early part of 2015. In view of this situation, a technical report drawn up with the support of CFG Services, and an expert assessment carried out by the BRGM, showed that the imposed pressure limitations could be raised. An order of the Prefect issued on 20 July 2015 ratified the proposals made. The decision had immediate effect, thus ensuring more satisfactory operations from August to December 2015, although the low steam problem has not been entirely resolved for the medium to long term.

An initial maintenance operation on n° 4 rotor wheel in the GTA B2 unit had become necessary in December 2014. Despite the work undertaken and the means deployed, the rotor wheel required further repairs on two occasions in 2015, in March and in July. These were "classic" incidents, which nevertheless substantially lowered B2 availability during the two months in question, resulting in a loss of more than 300 k€ in turnover.

Availability for the B2 unit was close to the estimated budget (88.44% as against 89.90%), a satisfactory performance that largely contributed to our overall result (although the bonus generated by the contract with EDF was cut substantially due to the difficulties that occurred in December 2014). Production from the B1 unit, which is operating as the "auxiliary" unit in the current situation, was ahead of target at 5 623 MWh as against 4 882.

FY 2015 thus ended with a net loss of -0.5 M€ as against a 1.3 M€ deficit in 2014. In addition to the above events, which were directly related to production, two further circumstances should be noted:

> hydrogen sulphide oxidation was effectively implemented;
> reinjection was technically "exemplary" (despite the "cold bubble" effect that appeared in the temperature profiles for the BO-6 well).

Finally, the Memorandum of Understanding signed by ORMAT and SAGEOS on 4 December formalised the equity issue process that began on 4 December 2014. The launch planned for the first half of 2016 will provide the company with the necessary means for an ambitious programme to develop geothermal energy in Guadeloupe.

A turbine at the Bouillante geothermal plant (Guadeloupe). © BRGM

Jean BERNARD
Chairman of Iris Instruments

Chairman: **Jean Bernard**
Turnover: **5.19 M€**
SERGAP holding (BRGM Group): **51%**
OYO holding: **49%**
Payroll: **26 employees**

For more information:
www.iris-instruments.com

Induced polarisation current recorder for deep mineral explorations.
© IRIS INSTRUMENTS

IRIS Instruments, specialises in geophysical instrumentation for subsoil explorations and monitoring, with applications in hydrogeology, geotechnology, environmental engineering and mineral prospecting. The company employed 26 people as of December 2015.

Turnover (excl. VAT) for 2015 was 5.19 M€, a little over the 2014 figure (5.17 M€). Exports during the year rose from 83% to 89% of total sales. Sales figures were highest in France, Italy, India and China, ahead of Saudi Arabia, Iraq and Peru, with total sales balancing out across the different continents.

The 2015 operating result shows a profit of 647 k€, as against 1 061 M€ in the previous year. With a positive financial result of 114 k€ and the benefit of a tax credit for research, the net after-tax result for 2015 shows a profit of 796 k€ as against 1 067 k€ in 2014. Iris Instruments will again offer shareholders a dividend, as in the 13 previous years.

Activities are increasingly competitive given the difficult economic context, and margins are accordingly tighter.

Our range of electrical resistivity equipment is still the most in demand, followed by the induced polarisation range. The current slowdown in the mining sector has

Training students in the use of magnetic resonance equipment for water prospecting in Rwanda. © IRIS INSTRUMENTS

not prevented our company from pursuing innovations in induced polarisation equipment: despite an unfavourable economic context, a new system of distributed receivers to obtain 3D images of mining targets at great depths has been launched on the market.

Sales promotion events were organised at trade fairs and conferences in France, Denmark, Italy, Greece, Russia, the USA, Canada, Brazil, Peru, South Africa, the Emirates, China and Australia.

Our range of electrical prospecting equipment was extended with a multi-transmitter multi-receiver resistivity apparatus designed for very rapid data acquisition. This product was developed in partnership with our two shareholders, BRGM and OYO, mainly for environmental applications.

In view of our development strategy and given that sales have been flatlining over the last three years, the shareholders asked the company to boost growth through technological innovation or by adapting to less cyclical markets than the mining sector. Thanks to our robust financial health, IRIS Instruments is in a position to invest in research, development and innovation in breakthrough technologies and to prospect for new markets, while awaiting an upturn in our traditional markets, which will continue to drive growth.

To support this development strategy, we have recruited four new employees, including a CIFRE doctoral student.

"Sales have balanced out across the different continents"

Jean BERNARD
Chairman of Iris Instruments

Boosting the distribution of scientific and technical knowledge

In keeping with its research and expert study missions, BRGM contributes to the dissemination of scientific and technical knowledge among the scientific community, professionals, planners and the general public.

Publications

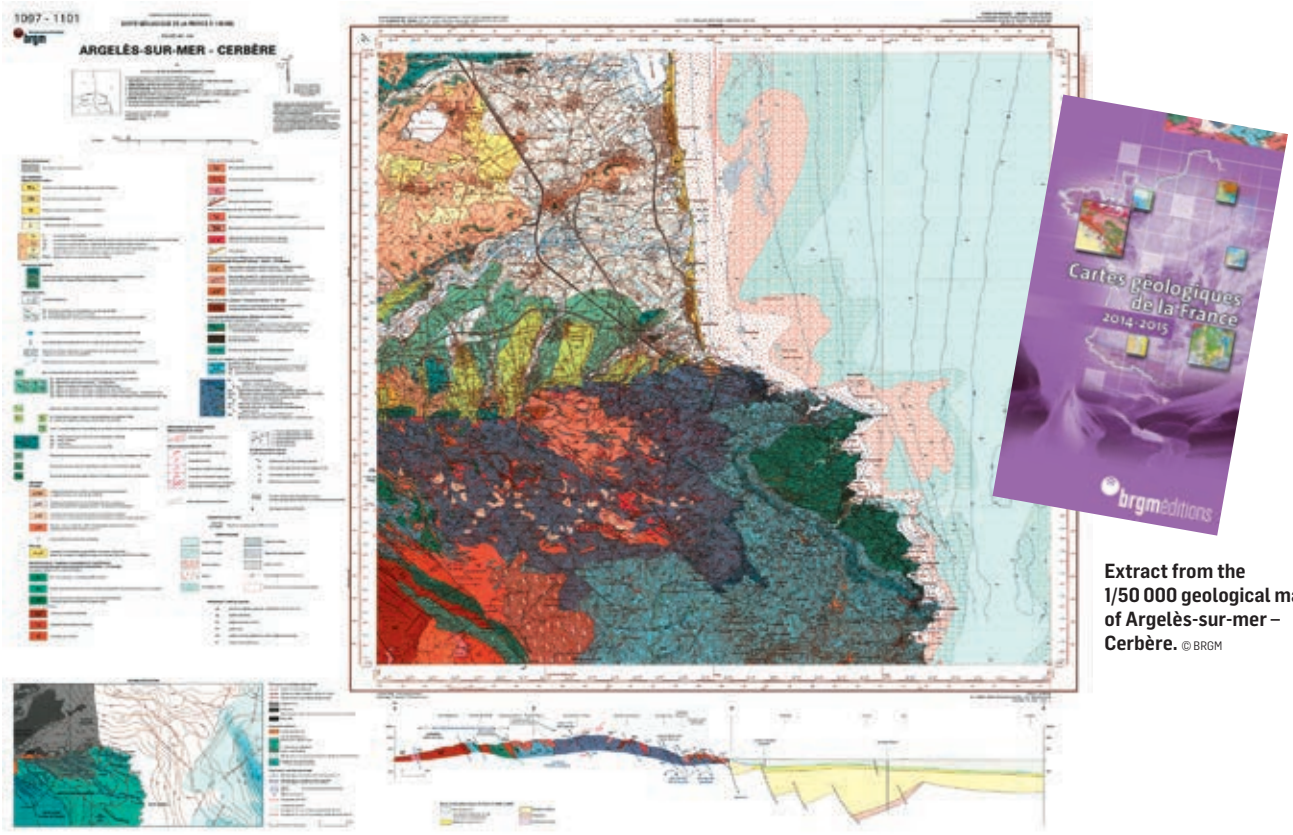
As the leading French-language publisher in the Earth Sciences, the BRGM's publications branch contributes to the recognition and visibility of our organisation among a broad readership in France and across the world.

The publications on offer cover all of the BRGM's disciplines, thus helping to achieve one of the goals laid down in the State-BRGM performance contract for 2013-2017: to "contribute to the promotion and distribution of knowledge and scientific culture in applied geosciences", by promoting scientific and technical advances and the value of the geological heritage.

Several important developments for the BRGM's publications division were consolidated during 2015. Following the launch of digital map sales on 1 January 2014, all geological maps, both print and digital, can now be purchased through a single online sales point. Secondly, a new editorial committee was established to take responsibility for driving and validating policies to be adopted in accordance with the BRGM's strategic orientations and with market surveys in the publishing sector. The other major project concerns preparations for the new management system required to handle the future online bookshop.

As is often the case for specialised publishers, the BRGM's publications branch also functions as a bookshop. While geological maps are still the BRGM's core publishing activity, the BRGM catalogue also includes publications ranging broadly over the Earth Sciences and organised into three editorial lines: educational books for young people, scientific and technical books and popular science, such as the two collections of field guides describing and explaining the French geological heritage. All these books are published in partnership with publishing companies or local authorities seeking to promote their natural heritage.

Search the full catalogue on line
More information at: *http://editions.brgm.fr*



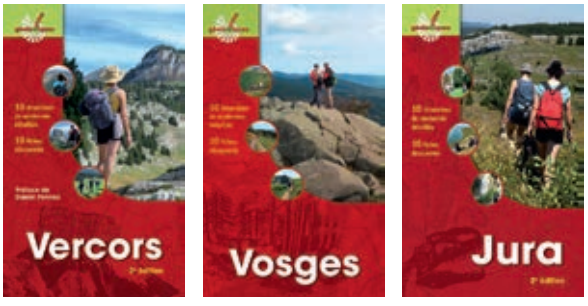
Extract from the 1/50 000 geological map of Argelès-sur-mer – Cerbère. © BRGM

Geological maps

Geological maps are essential sources of information for professionals, teachers, students and interested members of the public. As the foremost medium for geological information, they provide a synopsis of current knowledge, accurately locating a large amount of information on subsoils. They are essential decision-support tools for spatial planning, mineral prospecting, groundwater prospecting and protection, pollution control, natural risk prevention and the characterisation of local areas.

NEW PUBLICATIONS 2015-2016

Geological curiosities of the Loiret.
Co-published by the BRGM with the Loiret district council
Geological curiosities of Aquitaine.
Co-published by the BRGM with the Aquitaine Coastal Observatory
Geological curiosities of Martinique.
Co-published by the BRGM with Orphie



Geological Guides to the Vercors, 2nd edition
Geological Guides to the Vosges and the Jura, 2nd edition
Co-published by the BRGM with Omniscience

BRGM home page, Twitterhome page and our BRGM-Infos newsletter, Dec. 2015.

60 scientific success stories for a sustainable Earth

Issue N° 20: Geosciences to support innovation

Issue N° 32: Natural risks: protecting people and their environment

Issue N° 3: Geosciences, an integrated approach to regolith studies

Communication tools

The BRGM website

A web site that plunges its users into the world of the French Geological Survey to explore the many issues involving the Earth Sciences. The BRGM website offers over 1 000 pages of richly varied information that has been entirely rewritten to emphasise the diversity of the activities and projects conducted by the BRGM and its teams. The new site has received over 33 000 separate individual visits on average each month since its launch. We have over 6 300 subscribers to the BRGM-Infos newsletter and over 1 800 to our Twitter feed.

Géosciences magazine

Géosciences is a reference magazine on the Earth Sciences, designed to interface between different debates, different issues and different areas of research, and to highlight essential if sometimes conflicting points of view. The articles are written by recognised specialists in each field for a much wider readership than the scientific community alone, since the contents are of interest to anyone with a concern for sustainable development, from companies to NGOs and the wider public.

Géorama

A science magazine for the general public describing research projects and/or projects to support public policy development, industrial partnerships and, more generally, the BRGM's expert studies and services. It also aims to bring a broader perspective to current or emerging issues involving the geosciences.

R* Research Letters

Our R* Research Letters illustrate the BRGM's capacities for raising key issues for society, finding solutions by overcoming key scientific problems and producing concrete results. In each issue, a special feature addresses a topic of particular importance to society and involving the BRGM's different fields of activity.

MAIN DATABASES AND WEB SITES ON SOILS AND SUBSOILS

The BRGM's primary role is to discover, protect and promote the value of the Earth's resources.
Output from our research, public policy development support and service activities, both in France and abroad, is used to build and disseminate databases and websites on soils and the subsurface.

See our media catalogue at:
http://www.brgm.eu/news-media/liste-websites

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English translation: Ilona Bossanyi-Johnson. **Design & layout:** Efil 02 47 47 03 20 / www.efil.fr.
Printed by Imprimerie Vincent (Tours), approved by imprim'vert (charter on traceability, treatment and reduction of the environmental impacts of waste). Printed on paper complying with responsible management criteria. **Cover:** The ReunEM heliborne geophysics campaign (La Réunion). This project achieved full high-resolution coverage of magnetism and electromagnetism in La Réunion. Once processed, the data produced scanner-type imagery of the first 200 metres below the surface, which was subsequently used to support full investigations.

FRENCH NATIONAL GEOLOGICAL SURVEY

Geoscience for a sustainable Earth

brgm

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