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Environmentally sustainable mining in Europe

Contents

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Foreword

EurGeol. Vítor Correia, EFG President

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[1]

In the ‘90s, after getting my degree in geology, and inspired by a brief passage in the mining industry, I worked for more than a decade in the environmental impact assessment and permitting of mining projects. The focus of the analysis was, in those times, on nature protection and post-mining rehabilitation. Not sustainability. Sustainability and sustainable development only appeared in the debates after 2000[2], bringing to the discussion table the social and economic dimensions of extractive projects, alongside the environmental factors. Despite using the concept to underline the social and economic benefits of mining, I never truly believed that mining could be a sustainable activity, simply because mineral deposits are not renewable resources.

But I changed my mind in the last couple of weeks. In the middle of June I participated in the Resources for Future Generations 2018 (RFG2018) Conference held in Vancouver. The roots of this meeting can be tracked down to the International Union of Geological Sciences 2013 initiative, *“Resourcing Future Generations”*, and to work made by a group of geoscientists who pointed out the need for a globally coordinated approach to meet the raw materials needs of future generations[3]. The conference had the merit[4] of bringing together a diverse and vast group of people covering all the positions of the scale that ranges from wardens to exploiters of the planet. Despite the diversity of backgrounds and interests, I was impressed by the consensus around the need to increase the effectiveness of the extractive industry, ensuring the comprehensive exploitation of mineral resources and the minimisation of waste generated (aiming at zero waste)[5]. And this is a huge step towards sustainable development in mining because it minimises adverse environmental impacts, leverages social benefits (including the social acceptance of mining) and boosts economic wins (all costs considered).

On 27 June I participated in the pilot event of the World Forum of Raw Materials[6]. The audience was composed mainly of representatives of governments and academia, and the participants agreed on the absolute necessity of improving the international governance of

1 Brundtland, G., Khalid, M., Agnelli, S., et al., 1987. Our Common Future. United Nations. Retrieved from ***http://www.un-documents.net/our-common-future.pdf.***
2 I was not aware, until writing these lines, that the concept of sustainable development was developed and presented, as we know it, in 1987, by an independent committee of 22 members, nominated by the United Nations General Assembly, and headed by Gro Harlem Brundtland, the Prime Minister of Norway.
3 Nickless, E., Ali, S., Arndt, N., Brown, G., *et al.*, 2015. Resourcing Future Generations: A Global Effort to Meet The World's Future Needs Head-on. International Union of Geological Sciences. Retrieved from ***https://www.geolsoc.org.uk/~/media/shared/documents/RFG/RFG%20Full%20Report%20 2015.pdf?la=en.***
4 The conference was organised by the International Union of Geological Sciences (IUGS), the Canadian Federation of Earth Sciences (CFES), the Canadian Institute of Mining, Metallurgy and Petroleum (CIM), the Geological Association of Canada (GAC) and the Mineralogical Association of Canada (MAC).
5 This approach is being advanced since 2009. For more details on the concept see Green Mining - A Holistic Concept for Sustainable and Acceptable Mineral Production (2017) by Pekka Nurmi, retrieved from ***https://www.annalsofgeophysics.eu/index.php/annals/article/download/7420/6800*** and Transforming our world’s natural resources: A step change for the United Nations Framework Classification for Resources? (2018) by Julian Hilton *et al.*, retrieved from ***https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc9_apr2018/ece.energy.ge.3.2018.7_e.pdf.***
6 This is an initiative triggered by a European H2020 project headed by the World Resources Forum. EFG is a member of the Consortium and a workpackage leader.

mineral resources[7]. The timing for this seems perfect. In December 2015 195 countries signed the Paris Agreement and collectively agreed to strengthen the global response to climate change by reducing greenhouse gas emissions. The Paris Agreement was signed three months after the adoption of the United Nations 2030 Sustainable Development Agenda. These are twin plans for transformative progress, sharing a new narrative focused on meeting the needs of two key beneficiaries, "people" and "planet", through the common goal of sustainable "prosperity" for all[8]. If this prosperity is to be achieved and shared equitably, the manner in which we collectively manage and use the natural resources of the planet will be paramount. Why, how, when and where natural resources are discovered, produced, consumed, recovered and re-consumed will define more than any other activity whether or not we have succeeded[9].

The next day I attended the World Materials Forum[10]. The audience of this forum was composed mainly of representatives of the European industry. And I received two divergent insights (on top of the insights received in Vancouver and at the pilot event of the World Forum of Raw Materials) which convinced me that mining could be sustainable. The first insight comes from the motto of the World Materials Forum: *Use Smarter, Less and Longer*. Smarter means selecting the best materials for each function, less means improving resource efficiency and longer means extending product life cycles. Implementing this means we can cope with the increasing demand derived from global population and middle-class growth in the 21st century without increasing (much) the current levels of extraction of primary mineral raw materials – assuming, naturally, that the recycling efficiency will also improve, and that society won't be seeking other/new elements to satisfy demand from emerging technologies.

The second insight came from Robert Friedland[11]. Talking about the extraction of cobalt[12] in the Democratic Republic of Congo, Friedland highlighted that the biggest share of cobalt production in the world comes from a small region of a huge country (with an area that matches half the area of the EU 28 together), and that there are good prospects for cobalt production in many other regions of DRC – meaning that cobalt probably isn't as scarce as we usually think.

The combination of all these trends points to a positive outlook: the industry consuming less mineral raw materials; the mining industry approaching mineral deposits with comprehensive extraction methods, under a global governance framework, on a planet with important mineral deposits still to be found. This is a revolution. And Europe can lead it. We have a sophisticated and demanding legal framework that gives a say to communities and guarantees the adoption of effective environmental protection measures. We have a big potential for mineral exploration. We are already adopting green mining and zero waste generation policies in some countries. The European industry has high levels of resource efficiency and the European Union strongly supports research and innovation. On top of this, we have an important geoscience workforce capable (and willing, I'm sure) of backing this revolution. The articles in this number of the EGJ are a sample of all this. And I look forward to seeing mining become a sustainable activity in Europe.

7 The need for strong intergovernmental convergence on the governance of mineral raw materials is not a novelty. The International Resource Panel of the United Nations, the European Commission and the Organisation for Economic Co-operation and Development have all been voicing concerns on this topic.

8 Nationalism is naturally countering this narrative. However, the demand for more and diverse mineral raw materials to meet industry needs pushes up trade among nations.

9 Hilton*et al.*, 2018. Transforming our world's natural resources: A step change for the United Nations Framework Classification for Resources? United Nations Economic Commission for Europe. Retrieved from ***https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc9_apr2018/ece.energy.ge.3.2018.7_e.pdf.***

10 The pilot event of the World Forum of Raw Materials was organised in Nancy, France, back to back with the 4th World Materials Forum.

11 Friedland is an American-Canadian self-made billionaire and major player in the junior mining industry. Since the early 1980s he has specialised in securing funding for the exploration and development of mineral and energy resources and advanced technology ventures.

12 Cobalt is considered a critical raw material in several criticality assessments because it plays a critical role in batteries, it is difficult to substitute, and extraction is concentrated in a politically unstable country.

The hunt for phi structures

*Andre Lambert**

Phi (Φ) structures are geological entities that combine ring shaped fault segments with crossing shear zones. Their closeness to mineral occurrences is recognised but many geologists do not consider them useful for prediction of deposits and challenge their detection. This paper reviews the geology, genesis and economic worth of the structures, focusing on gold mining in Europe. In addition, 203 large mines or mining districts worldwide are investigated for the presence of phi structures. Methods used to identify them include Computer Vision and Machine Learning algorithms, Hough and Radon transforms, and global gravity gradient maps. Results show phi patterns in the vicinity of mining in 61% of the cases. A companion web archive provides learning images, routines and detailed examples.

Les structures Phi (Φ) représentent des entités géologiques qui associent les failles segmentées de forme annulaire à des zones de cisaillement. Leur proximité avec des occurrences minéralisées est reconnue mais nombreux sont les géologues qui les considèrent comme sans valeur prédictive de gisement et contestent leur découverte. Cet article passe en revue la géologie, la genèse et l'impact économique de ces structures, mettant l'accent sur l'exploitation des mines d'or, en Europe. Qui plus est, 203 gisements ou districts miniers d'importance mondiale sont étudiés pour l'éventuelle présence de structures phi. Les méthodes d'identification utilisées incluent l'Imagerie digitale et les algorithmes d'apprentissage automatique, les transformations de Hough et Radon et les cartes du gradient gravimétrique régional. Les résultats indiquent la présence de schémas phi à proximité de gisements, dans 61% des cas.
Une notice, archivée sur le web, procure un apprentissage par images, fournit des procédures et exemples détaillés.

Las estructuras phi (Φ) son formaciones geológicas que combinan segmentos de fallas de forma circular con zonas de cizallamiento perpendiculares. Su similitud a sucesos minerales es reconocida, pero muchos geólogos no las consideran útiles para la predicción de depósitos y desafían su detección. Este artículo analiza la geología, génesis, y valía económica de estas estructuras, centrándose en la minería de oro en Europa. Además, 203 minas de gran escala, así como los distritos mineros de todo el mundo están investigando la presencia de estructuras phi, la transformada de Hough y la de Radon, y los mapas de gradiente de gravedad a nivel global. Resultados muestran patrones phi alrededor de la minería en el 61% de los casos. Un archivo web proporciona imágenes de aprendizaje, rutinas y ejemplos detallados.

1. Introduction

Phi (Φ) structures are tectonic sets combining ring-shaped fault segments with crossing shear zones; they cover surfaces between a few to several thousands of square kilometres. Their proximity to mineral occurrences is frequent and intriguing: many among the Φ patterns cover or are tangent to deposits of iron, gold, copper, lead-zinc, diamonds, rare earth, lithium or uranium.

The concept of the phi structure is a catchall. It includes identified meteorite impacts, alkaline ring complexes and intrusive stocks calderas as well as discrete features without any surface clues to their origin. The distinction between magmatic or impact genesis often remains blurred: large impacts are frequently followed by intrusions. When the surface scar is eroded, the remaining phi signatures are quite similar in both the intrusive and impact cases: it is often impossible to distinguish them without deep drilling or a seismic survey.

Many geologists have tested the predictive capacity of the phi structures. Outstanding among them is O'Driscoll (1980, 1985) who gave credit to the phi concept for contributing to the Olympic Dam mine discovery. O'Driscoll coined the "hydrothermal highway" metaphor (***Figure 1***). Witschard (1984), Eggers (1979, 1981), Saul (1978), Kutina (1995), Robinson (2005) and Bubner (2000) present western world examples. Florenskii (2006), Gavrilov (2012) and Piloyan *et al.* (2016) give abundant references to eastern European publications about these structures and their relations to ore deposits (note that citations given in grey are for references listed in the companion web archive). Watchorn (2017) maintains a website outlining giant ring structures in Western Australia and discusses their possible ties to gold and nickel occurrences. All of the studies converge in showing that the phi structures are favourable sites for hosting mineral occurrences: they combine a probable heat gradient with a dense fracturing pattern.

In this study, 203 large mining sites or districts were searched to test the presence of phi structures. A few, mainly from the gold exploration scene, are described here to illustrate the concept.

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2. Methods

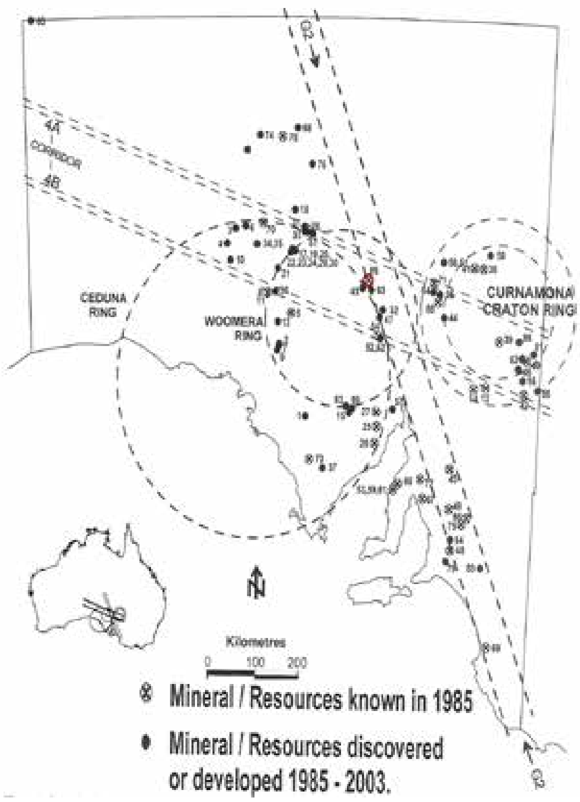
The main challenge was to design a way to locate the structures in a reproducible, probabilistic way so as to deflect identification critics: the human eye is prone to find patterns where there are none...and to ignore obvious ones. Detection methods are presented for the ring and for the cross-cutting components.

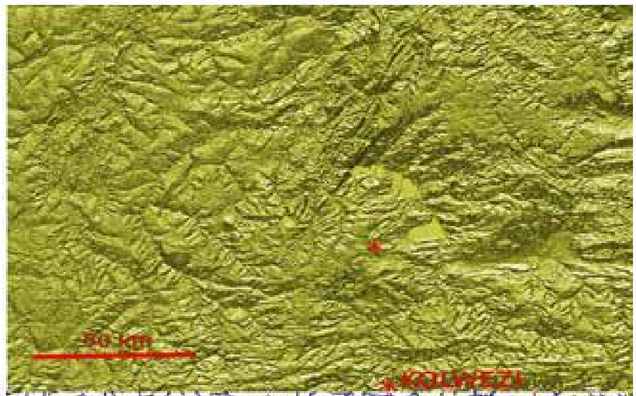
2.1 Rings

Digital terrain models (DTM) provide the best support for locating phi structures; the most efficient algorithms found are Hough transform and the Convolutional Neural Networks (ConvNets) image recognition.

2.1.1 Computer Vision/ Hough Transform

The Kolwezi ring structure in the south of the Democratic Republic of the Congo was chosen as first test example. The area is the largest cluster of strata-bound copper occurrences in the world (Broughton *et al.*, 2010). The 40 km wide half-ring is easy to spot on the digital elevation models; (in this





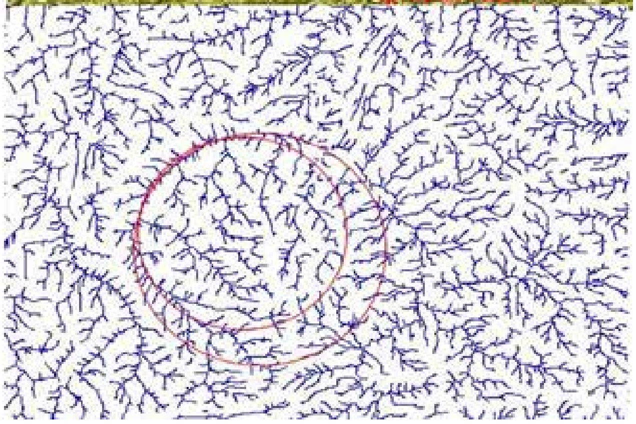


Figure 1 (left): Discovery of Olympic Dam by O'Driscoll, regional view from Bourne and Twydale 2004, modified. Red dot: Olympic Dam (South Australia). - Figure 2 (upper right): Illuminated DTM of Kolwezi area. The diameter of the phi structure spans over 40 km. The red star is the location of Kolwezi town, Democratic Republic of the Congo. - Figure 3 (lower right): Drainage network calculated from above DEM, same frame.

case ALOS - Jaxa 2018 - ***Figure 2***).

The Circular Hough Transform method is expected to find triplets of (x, y, R) that belong to circles in a given image with a high probability. The algorithm has been implemented on Octave software (Octave 2018); it was applied to river network images generated from digital elevation data with SAGA Gis (SAGA 2015) (***Figure 3***). The Hough transform plane reflects a probability distribution (***Figure 4***) and shows that a properly shaped circular feature is very unlikely to emerge at random.

The Hough transform plane with the peak response from the twin curved segments is shown in ***Figure 4***; the circle segment is confirmed by more than six standard deviations.

2.1.2 Machine learning/ Neural Networks

Convolutional Neural Networks (ConvNets) have been developed during the last decade. ConvNets derive their name from the "convolution" operator which scans an input image, extracts features and give them a rating through a combination of weights and biases learned by stacked layers of digital neurones. Convolution preserves the spatial relationship between pixels by learning image features using small squares of input data (Walkarn, 2016). The number of earth and planetary sciences applications is growing exponentially (e.g. Palafox *et al.*, 2017; Kaggle website, 2017).

The most popular ConvNets are fed with several million images and trained for weeks on supercomputers. Some of the features picked up by them are useful to most computer vision problems and can be transposed for targets other than those initially planned. Smaller vision studies typically re-use the trained lower parts of larger nets to rebuild a new and efficient network for their own purposes, with a much lower computation cost (Chollet, 2016, 2017). VGG16 and Xception nets were tested here, the program used is Keras (2017), a Python wrapper applied over Theano (2017) or Tensorflow (2017); both are math libraries designed to handle large tensors. The network was trained on 3,640 images and validated on a different set of 1,160, similar to those in ***Figure 5*** (224×224 or 299×299 pixels). The prediction of whether or not a phi structure is on the image has an accuracy of about 91% on VGG16 net with 4% false negative and 5% false positives, while 93% accuracy is reached on Xception.

Some layers of the networks respond particularly well to phi characteristics; for instance layers 15 and 16 of VGG16 react to curved edges while layers 25 and 27 respond to circular "cloudy" features, as shown in ***Figure 6***. Those four layers can be combined into a specific filter which can be applied over wider images applying a method described by Perone (2016) and Blier (2016). The identified PHIs can be tested on smaller images for a final diagnostic (***Figure 5***). Routines and methods are given and discussed in the companion web archive. The grey shadings in ***Figure 5*** represent illuminated DTM scenes containing phi structures.

2.2 Cross-cutting lineaments

Shear zones cut across and may truncate the ring structures. A range of methods are available for their detection, starting with the plain visual study. To thwart personal interpretations, a Radon transform algorithm may be used to outline the most significant bundles of lineaments. Radon (Hoilund, 2007) is an integral transform which takes a function f defined on the image to a function *Rf* defined on the two-dimensional space of lines in that same

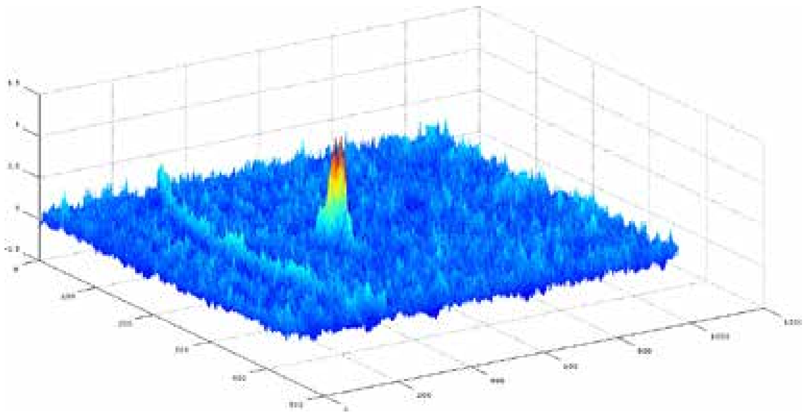


Figure 4: Transform plane with peak showing the centre of segments highlighted in Fig. 3 (Octave routine is given in the companion web archive).

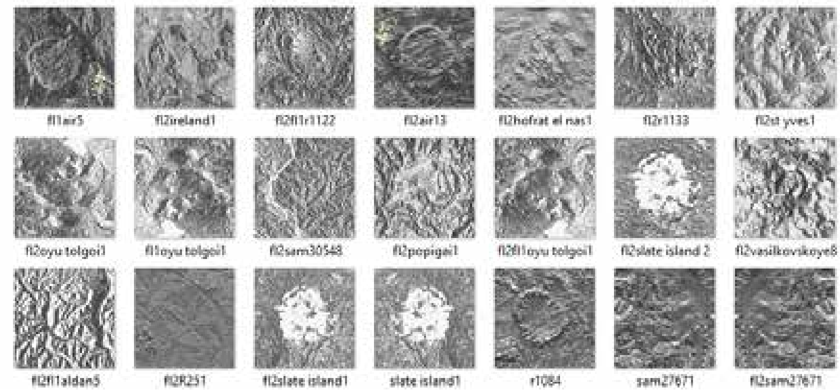


Figure 5: Extract of images library (all here are positives, i.e. they contain one or several PHI structures; the plain, negative, images are available in the archive).

image. The value at a particular line is equal to the line integral of the function over that line. Said plainly, with a given orientation theta, all pixels in the image are looked across "rays" perpendicular to that section and the aligned pixel values are summed up (***Figure 7***).

Shear zones can be detected from geophysical data, when available. Gravimetric or magnetic gradient maps, like TXX or TYY, are very sensitive and best for detecting crossing shear zones at a high angle. Even low resolution surveys (***Figure 8***) like global gravimetric syntheses may give reasonable indications for large crustal shears.

3. Case Histories, Geological Context

Three origins are possible for phi structures: meteorite impact is exogenous while the other two are endogenous: magmatism and fluids buildup. Phi structures can be transposed into overlaying sediments or a volcanic blanket, deposited later, through isostatic corrections. The geothermal cells have practical engineering and environmental applications.

3.1. Impact origin

At Vredefort RSA, one of the largest impact sites studied worldwide, the initial shock was dated at 2023+-4 Ma. After that, "anatectic granites" raised and metamorphism developed, giving dates at 2017 +- 5 Ma (Reimold, 2015), interacting with previous gold occurrences.

Apart from Vredefort and a few other examples listed by Grieve (1994, 2005) and Reimold (2005), it is extremely difficult to prove a meteoritic impact origin for an old and deeply eroded feature. They are always largely eroded, shatter cones are washed out and fresh pseudotachylites remain difficult to spot and diagnose. Siljan impact is presented below and other examples are discussed in the companion web archive.

3.2. Magmatic origin

Wall *et al.* (2005, 2014) propose the "TAG: thermal aureole gold" model. Although not designed for phi structures, the model outlines the centres and ring peripheries as target areas. Part of Wall's discussions are on the Muruntau deposit, which is on a phi structure. It should be observed that the true Muruntau ring structure is eight times larger than the one shown in Wall's block model (***Figure 9***) and deposits are not in the same structural position.

The rosary of gold deposits along Muruntau is a good example of how the crossing shear zone influences the mineralising process. Copper/gold porphyries are presented below in the European test section;

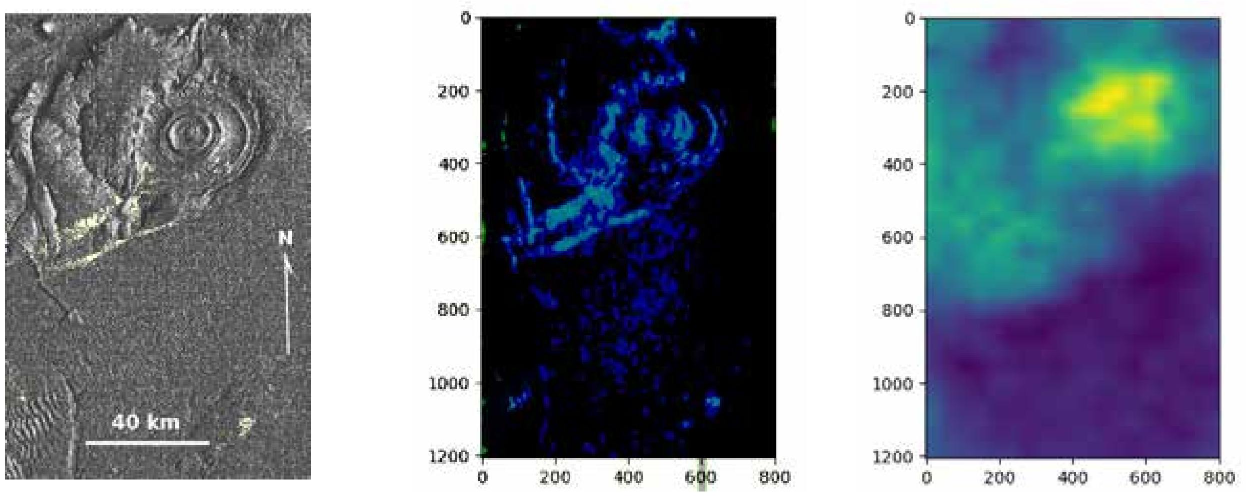


Figure 6: Test images over Richat structure in Mauritania: left: DTM; centre: combined layers 16,25,27 of VGG ConvNet; right: heatmap (the lighter colours are warmer).

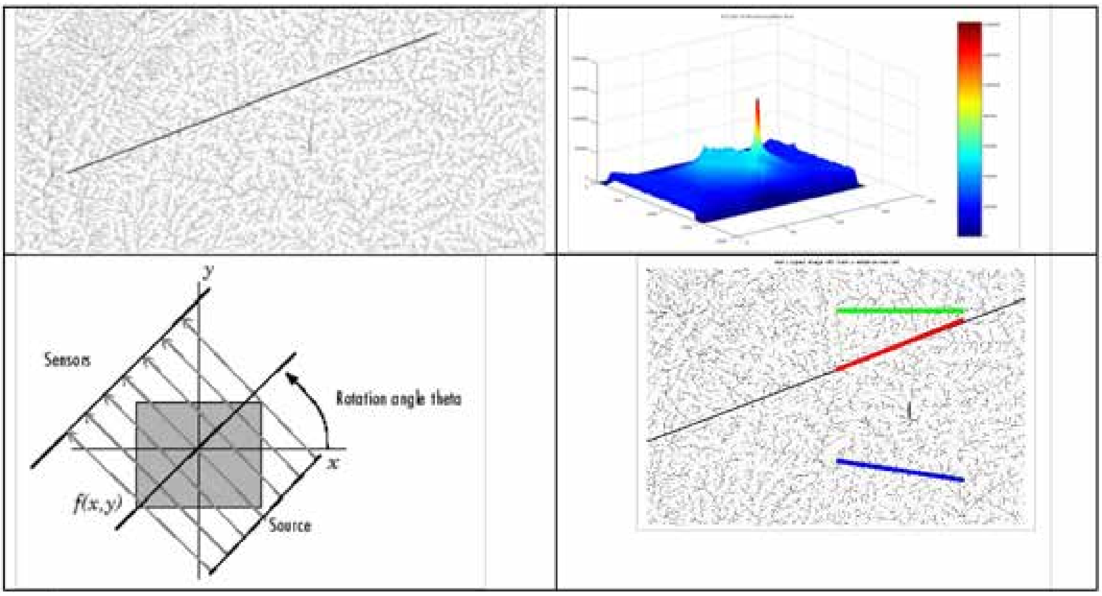


Figure 7: Clockwise: 1- original drainage map with test line drawn, 2 - radon peak in 3D corresponding to the black line, 3 - the three best alignments , 4 - caption to show radon projection mode. (Octave routine is given in the companion web archive)

kimberlites are other examples of magma related structures.

3.3 Gases: structures without magmatic or volcanic indications

Most of the phi occurrences reviewed do not give any indication of a significant intrusive body nearby or of a significant volcanic activity suggesting calderas. This is particularly observed for gold deposits in West Africa. These Φ structures might originate as a ground swell under a pocket of gases, fluids or dry steams which later escaped, leaving scant traces of their passage. Gilat (2005, 2012) indicates that tremendous gas activities are generally overlooked.

3.4 Diachronic effects

Interaction with ore deposits can be less than obvious. While phi structures may directly remobilise and enrich earlier deposits, isostatic replays can drive the hydrothermal systems upwards, improving the economic value of later stage occurrences. Some examples:

- The Vredefort structure was impacted before the Karoo deposition but ring faults have replayed and penetrated the Karoo cover;
- In the Central African Republic, Bakouma U mine is in Neoproterozoic sediments but ring fractures nearby cut across nappes of various ages;
- In Mali, near Sadiola, some ring fractures stop at the escarpment of the Infracambrian sandstones while several structures nearby are developed in the sandstones, also on the Senegal side,
- the phi structure west of Kolwezi is covered by the NW thrust sheet; however, later ring cracks in the neighbourhood penetrate the overlaying nappe.

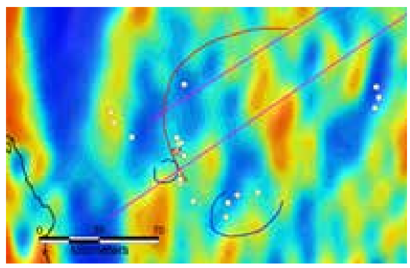


Figure 8: Tasiast Gold Mine (Mauritania), TXX gravity gradient map (ring segment in red, mine location shown with the red symbol, white circles: gold anomalies, in blue are possible other rings. Range: -50 to +50 Eotvös)

Phi structure collapse generates three associated fracture types: steep cracks along the ring structure, décollement on top and en echelon faults within the perimeter. The collapse environment could explain why, in

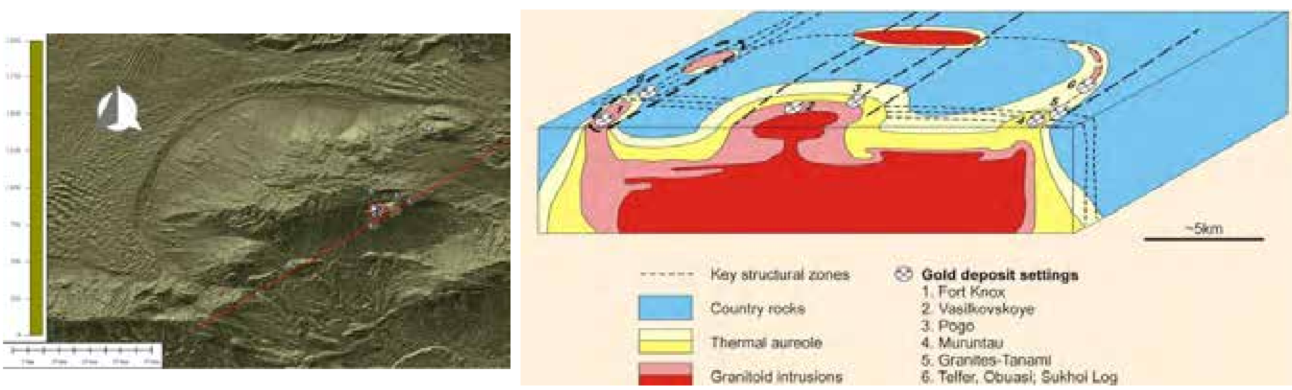


Figure 9: Muruntau shows a typical phi pattern. Left: view from SE, the radius of Muruntau structure is about 40 km. Right: TAG model from Wall (2014). Symbols are for mine sites.

some copper, uranium or gold provinces, steep rich shoots coexist with strata bound lenses or with abundant dolerite sills (e.g. Rusin et al., 2007; ***Figure 10***).

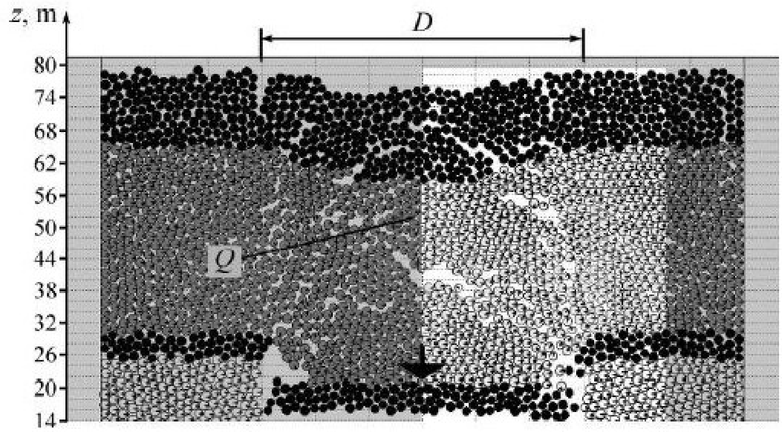


Figure 10: Sub-level caving models, applicable to the ring features (from Rusin et al. 2007).

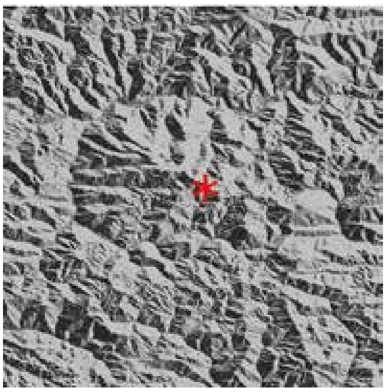


Figure 11: Rosia Montana (diam. 12 km), N is up. Source: ALOS

Figure 12: Rovina (diameter 8 km), N is up Source: Google Earth

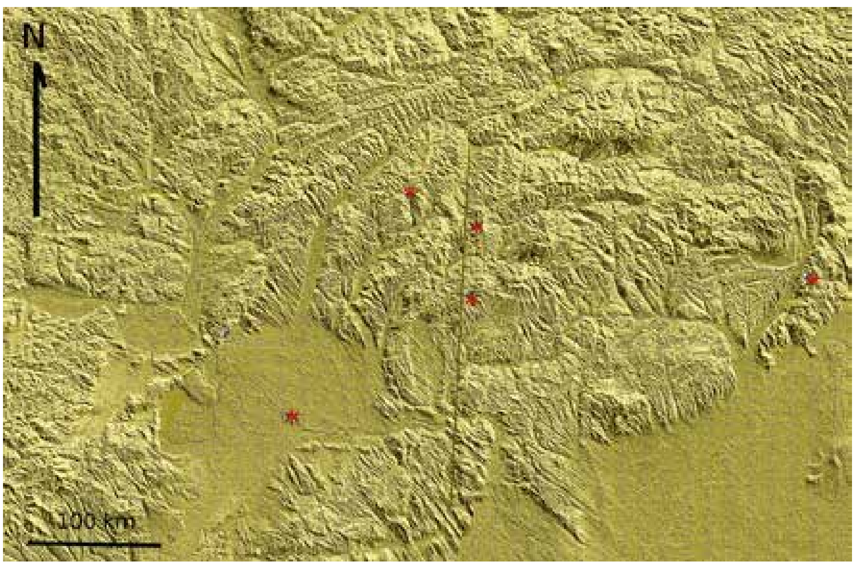


Figure 13: Giant ring structure of Slovakia with major gold occurrences in red (diam. 200×300 km). Grey line = crossing shear. Source: ALOS

3.5 Geothermal and Environmental aspects

Phi structures provide valuable aquifers; their permeability frame must be properly understood when conducting impact studies, and all the more so when exploiting water next to mineral deposits or mines that the structures may host.

A quick search over the Internet with the three words "geothermal-ring-structure" will return several hundred relevant references. Most relate to tertiary or recent volcanic calderas of relatively small size, but a number of them are linked to older and larger structures, including known impacts. For instance, in Sweden, three old impacts were drilled and found to have geothermal potential: Siljan, Bjorko and Dellen. Unfortunately the old fracture network became cured with calcite, quartz or albite. Bjorko, at the SW outskirts of Stockholm, is plugged by calcite and could be exploited after fracking, but more economic sources of warm water are available at the moment (Henkel *et al.*, 2005). The Siljan impact structure is about 50 km wide, the largest in Europe, with two lead zinc deposits at its SE edge and showing seeps of oil.

4. European Test Set

203 large mines or districts worldwide were tested with the above methods for their possible associations with phi structures. Of these, 61% were found touching or within phi structures (see list and images in the companion archive). Findings related to European gold mines and districts will be discussed here.

The largest gold deposit in Europe is Rosia Montana (Gabriel) in Romania. This is a copper-gold porphyry that gives a small but distinct phi signature (***Figure 11***). The nearby advanced project, Rovina, can be spotted on Google Earth (***Figure 12***).

It is relatively straightforward to identify a number of similar porphyry signatures around the Carpathian arc: in Romania, south of the Carpathian Range, there are for instance the Rinink and Horezu rings. Other provinces with similar signatures are Biely Vrch and Kremnica in Bohemian Slovakia, Kirovorhad in Crimea, Kisladag (Gumuskol) and Ovacik in Turkey, Pribram in Tchequia and Transkarpathia in Ukraine, as well as those in West Turkey. One fascinating case is the giant oval structure covering Slovakia (***Figure 13***, major gold occurrences in red).

The other European province showing significant gold is the Central Lapland with its greenstone belts in Finland and Norway. Phi structures are more difficult to spot in northern latitudes; their signatures fade relatively quickly: moraines, lakes and glacial streaks can mask them completely (***Figures 14 and 15***). Training models specific to glacial environments should be studied separately (Witschard, 1984; Krøgli 2008, 2010).

The data set on European targets, comprising images and ConvNets predictions, is available in the companion archive.

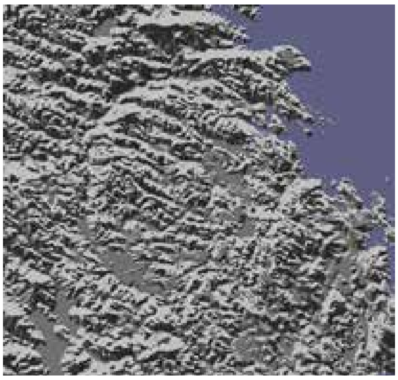


Figure 14: Skjellefte ring (diam. 35 km). Source: SRTM

Figure 15: Possible ring in Karasjok Province (diam. 20 km). Source: SRTM

5. Conclusion

When the first Landsat images came out phi structures became familiar to geologists. But a barrage of criticism, focusing mainly on their identification, has since pushed them back in limbo.

In this study, ring structures were searched for with the techniques described in the vicinity of 203 large mineral deposits or districts worldwide. An association with ring features was found in 61% of the cases, which is in the range of previously published evaluations (Bubner, 2004; Bourne and Twydale, 2004). The structures that were identified are definitely not figments of the imagination: their detection was monitored effectively and reproduced using different methods.

In spite of the concept being a "catch all", the presence of a phi structure pays off and therefore it should be looked for as a standard procedure, whatever its genesis may be. If a phi structure is detected, it can add a plus to any exploration effort or even give orientation to new research. When present, phi structures are parts of the environment and should be identified for their key role: it is tempting to extend O'Driscoll's "hydrothermal highway" metaphor to "hydrothermal roundabouts" for the phi structures, as they focus and redirect the transit of water.

Supplementary data

The companion web archive with all the programs, cases, images used and detailed bibliography is available at GitHub: ***https://github.com/lambertgeo/PHI*** .

Acknowledgments

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Mining non-renewable mineral resources in a sustainable way

*Tommi Kauppila**

The concept of environmental sustainability is crucial for the mineral sector, which utilises non-renewable natural resources. This paper introduces concepts that allow sustainable mining. The natural capital lost during mining can be substituted with other forms of capital, and revenues from mining are invested in reproducible capital or renewables-based substituting materials. Furthermore, a deposit-based sustainability model is described in which the ability of future generations to utilise mineral deposits rather than minerals themselves is intentionally maintained through investments in exploration, data collection, research, and development of improved technologies. At the same time, any losses of natural capital during mining are minimised and attempts are made to maximise the local social and economic benefits in a sustainable way.

Le concept de durabilité environnementale est incontournable en secteur minier qui utilise des ressources naturelles non renouvelables. Cet article introduit le concept de durabilité applicable au secteur minier. La perte de capital naturel durant l'exploitation peut être remplacée par d'autres sortes de bénéfices, et les revenus miniers sont investis en un nouveau capital ou en matériaux de substitution, fondamentalement renouvelables. De plus, un modèle de durabilité en gisement minier est décrit pour lequel la capacité des générations futures à utiliser les gisements miniers plutôt que les minéraux eux-mêmes est intentionnellement sauvegardée par l'intermédiaire d'investissements en exploration, en acquisition de données, en recherche et en développement de technologies de pointe. En même temps, toutes les pertes de capital naturel en exploration minière sont minimisées tandis que sont maximisés les bénéfices locaux concernant, de façon durable, les volets social et économique.

El concepto de sostenibilidad medio ambiental es crucial para el sector de la minería que emplea recursos naturales que no son renovables. Este artículo presenta una serie de conceptos que hacen posible la minería sostenible. La pérdida de capital natural que tiene lugar durante la minería, puede ser reemplazado por otras formas de capital, y las ganancias de la minería se pueden invertir en capital reproducible o en la sustitución de materiales basada en renovables. Además, el modelo de sostenibilidad basado en depósitos se basa en la habilidad de las futuras generaciones para utilizar los depósitos minerales en vez de minerales, mediante la inversión en exploración, recopilación de datos, investigación y desarrollo de tecnología mejorada. Al mismo tiempo, las pérdidas de capital natural durante la minería son minimizadas y se intentan maximizar los beneficios locales, sociales y económicos de una manera sostenible.

Sustainability, environmental sustainability, and sustainable development

Sustainability is one of the most commonly used buzzwords of our modern, environmentally conscious society. As a concept, *sustainability* is the ability of systems and processes to remain functional and continue their intended behaviour, basically indefinitely. From a human point of view, sustainability refers to our ability to manage environmental, economic, and social issues and to maintain these 'pillars of sustainability' in the long term.

For a long time, sustainability was considered to be more or less synonymous with *sustainable development*, the most popular definition of which appears in the Brundtland Commission's final report in 1987 as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The report emphasises that a new era of economic growth is required to meet even the essential needs of people in a world where poverty is widespread. The Brundtland report also points out that environment and development are inseparable, because the environment is where we all live and it does not exist as a sphere separate from human actions and needs.

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To solve the sustainability problem of the human economy, the *environmental sustainability* part of the equation also must be balanced. Since the seminal paper of Daly (1990), environmental sustainability has commonly been divided into three conditions that need to be satisfied: the harvest rates for renewable resources should not exceed their regeneration rates; the rates of waste emissions should not exceed the natural assimilative capacities of the ecosystems into which the wastes are emitted; and the depletion of non-renewable (exhaustible) resources should be matched by the rate of creation of renewable substitutes for these resources.

Non-renewable resources and sustainable development

Non-renewable resources, such as those obtained from mining, are particularly problematic in the sustainability context due to their inherently finite quantity. Fortunately, many non-renewable materials, especially metals, can be reused and recycled many times over without losing their intrinsic properties. Many products that are made of metals also stay in use for long periods of time. However, sustainability is a critical issue for the primary mineral sector, which is mining deposits that future generations could also utilise to meet their material needs.

For utilisation of non-renewable resources to be sustainable, the concept of *weak sustainability* needs to be invoked. It allows the use of natural capital (e.g., mineral deposits) as long as the capital lost is substituted with an equal amount of other types of capital such as manufactured, human or social capital. This is taken into account when investing the revenue generated by resource utilisation in reproducible capital such as machines (Solow, 1973; Hartwick, 1977). Weak sustainability is in agreement with the human-centric, Brundtland type of sustainable development which emphasises the alleviation of poverty and both global and intergenerational equity. In addition, many new environmental and energy technologies are based on the use of technology metals and other mineral-based materials, enhancing the environmental pillar of sustainability.

The Daly type of substitution is more restrictive than the interchangeability of different forms of capital in the concept of weak sustainability. Daly emphasises efforts to directly substitute non-renewable materials with other, renewables-based materials (or energy) as the main form of substitution to achieve 'quasi-sustainable' development. This is a more technically oriented approach and, if successful, is especially beneficial for the environmental sustainability pillar.

Minerals are mined from deposits

Besides substitution between different types of capital or between types of materials, a third type of substitution can be envisaged for the mineral sector. A unique feature of the mining industry is the concept of commercially valuable (ore) deposits in which minerals and elements are found in concentrations, volumes, and forms that provide for technically feasible and economically viable mining. It is these deposits that future generations also could benefit from, but individual deposits and their geodiversity are eventually depleted if we mine them now.

While it may be theoretically possible for humankind to mine out the whole crust of the earth, this is exceedingly difficult in practice. At least the topmost two kilometres of the 30-50 km thick, 150 × 106 km^2 continental crust are within reach for humans, even with current mining technologies. For the foreseeable future, therefore, we can make an assumption that, assuming high levels of recycling, the earth's crust as a whole contains enough useful minerals and elements to satisfy the needs of a human population of a size that the renewable resources on Earth can sustain. However, mineral deposits that readily lend themselves for economically and technically feasible mining are in much shorter supply. The *deposit-based sustainability* approach thus presents us with a third mode of substitution unique to the mining industry – the possibility to identify new mineral deposits and develop methods to utilise them for future generations. In the following sections, individual approaches to make mining of non-renewable materials more sustainable are discussed in more detail.

Maintaining our stock of identified mineral resources through public and private research

To replace the deposits that we exhaust by mining, we must identify and study new deposits, also considering future generations and the very long lead times from prospecting to mining. A major part of this work must rely on commercial exploration activities. However, exploration is a high risk economic undertaking with low and declining success rates (see e.g. Grennan & Clifford, 2017). The attractiveness of a region for exploration and mining investment depends on several factors such as the geological potential, security of tenure, effectiveness and predictability of the administrative process, manageable taxation and trade regime, and adequate infrastructure.

The geological potential of a region may seem like a fixed endowment, but even this feature can be improved, or at least boosted. This is done by investing in high quality geological research and education, and in collection, management, and delivery of geological, geophysical, and geochemical data. Modern methods for digital geodata management, analysis, presentation, and delivery provide unprecedented possibilities for disseminating geological databases to promote exploration. In addition, a great deal of progress has been made in the field of standardisation of spatial data specifications and interoperability of spatial data sets and services in Europe. It makes a lot of sense to invest in national level data management, attempting to collect all relevant data from all sources and manage them in a coherent way.

Besides the geological potential and geological databases, exploration and mining companies look at what is commonly called the policy potential of the jurisdiction. It consists of factors such as the administrative processes regarding exploration and mining projects, security of mineral tenure, public acceptance of mining, the taxation regime, human and physical infrastructure, and trade and labour conditions. A clearly stated and widely accepted mineral policy is essential in informing investors about the intentions and priorities of the jurisdiction regarding the mineral sector. The policy should be implemented efficiently through consistent regulations and ensure conditions that are scientifically valid and protective of the environment, combined with the ability of the authorities to plausibly enforce them. This is the easiest way for a company to show stakeholders and its shareholders that it is operating responsibly.

In many cases commercial exploration activity is not enough to increase the stock of identified mineral occurrences for deposit sustainability. Commodities and deposits that cannot yet be utilised commercially should still be studied for future needs, and the role of public actors such as geological surveys and research institutes is essential here. Public institutions can look for emerging minerals and elements, for instance those with potential to substitute current commodities or elements that can be used in cleantech applications. In addition, more attention can be paid to such minerals in current exploration projects, even if the primary target minerals are conventional ones. A special case here is scanning deposits for minerals that could be used at the mine site itself, typically for environmental applications such as water treatment or waste storage facilities.

Responsible mining is based on viable mines

Environmentally responsible mining is only possible with healthy projects. Not only is it necessary to include all foreseeable environmental expenditures in the feasibility studies, including costs of mine closure and post closure activities, but also to do this with a large enough margin of safety against market fluctuations. This is important especially because poorly planned and premature mine closures can be detrimental from an environmental point of view. In addition, only economically sound mining projects are capable of minimising any mining-related losses of economic, social, and natural capital to make mining more sustainable. They are also in best position to sustain local benefits from mining, both during the life of the mine and after mine closure.

Sustainable mining of individual deposits

Besides maintaining the inventory of identified deposits, individual deposits need to be utilised prudently to minimise any unnecessary losses of natural capital and to maximise the benefits from the project. To this aim, the treated ores must be utilised to the fullest and deposits mined wisely, the lives of mines and their infrastructures must be extended, and waste rocks taken for beneficial uses.

Mining, crushing, and grinding consume a lot of energy and processing typically requires considerable amounts of water. Therefore, it makes sense to utilise the crushed and ground ore as fully as possible. This means recovering as many commodities from the ore as possible and looking for possibilities to use the rest of the material, e.g. for cemented paste backfilling. Fractions that have potential to be valuable at a later stage can be separated and stored for future markets, especially if their removal results in cost savings in waste management.

In addition to utilising the comminuted ore to the fullest, care must be taken not to waste any of the ore in the mining phase or sterilize the rest of the deposit by making its future utilization difficult. Geometallurgical approaches have become a common practice in the industry and this holistic view of the deposit and its processing contributes a great deal to making mining more sustainable. All this needs to be based on adequate drilling of the deposit and skilful modelling of the results to determine optimal cutoffs and processing pathways for the ore.

Environmental sustainability can in many cases also be boosted by seeking to extend the lives of existing operations by brownfield and deep ore exploration. Instead of opening several mines with their own processing plants and waste facilities, well managed single sites could be a more environmentally benign option. Utilisation of existing and shared infrastructure makes sense if deposits are available within reasonable transport distances.

Minimising local impacts and maximising long-term benefits

In addition to utilising the deposit wisely, all other losses of natural capital should be minimised to make mining as sustainable as possible. The highest level of environmental performance is called for here and industry-specific research and development is required to tackle the unique issues in mining that affect environmental management.

Mining operations typically rely on economies of scale to control their operating costs. Processing large quantities of ore requires considerable amounts of water that need to be managed. While other water intensive industries can seek for locations near large water bodies, the location of a mine is fixed at the deposit. After processing, most of the treated ore becomes waste, the amount of which can be considerable. Furthermore, some types of mining waste are reactive and may produce acid, metal-laden drainage for long periods of time if not properly managed. The long timescales involved and the fact that mines have an inherently limited lifetime require that special attention be paid to mine closure and the post-closure period.

Despite these challenges, environmentally responsible mining is possible if the unique features of the industry are taken into account. Tailored environmental management methods for mining are available and best practice manuals and guidance have been published for various topics such as conducting EIAs for mining projects, waste management, acid drainage management and mine closure. The availability of skilled environmental professionals, consulting companies, authorities, and researchers is critical for a properly managed mining industry. Nevertheless, it is clear that the industry is moving towards low impact, low waste mining in which most processes happen underground and any moving of materials is minimised, contributing to the lowest possible losses of natural capital during mining.

According to the principles of weak sustainability, low impact mining should be complemented with measures to ensure sustainable social and economic benefits locally and regionally. This work starts already in the early EIA phase and with early mine closure planning, where post mining land uses are discussed with the local stakeholders. As a general rule, best outcomes are only possible if all planning is done in close collaboration with the local authorities and other stakeholders. A mining project is a large industrial undertaking that in many cases affects the regional labour markets, economy, and demand for public services and housing. However, all mines eventually close and economic diversification has to be promoted early on to secure long-term benefits from the mining project.

Sustainable mineral policies

Besides helping to attract exploration activity through stability and predictability, mineral policies are also one of the main vehicles to promote the sustainability of the mineral sector as a whole. Governments and public administration can manage and stimulate the mineral industry and sustainability aspects can be included in this work. For successful political decision-making on sustainable mineral industry, data and information on the sector needs to be collected, analysed, and distributed in a suitable format (see e.g. Machacek *et al.* 2017). Data are needed not only on the primary minerals but also secondary sources, because recycling and anthropogenic deposits are becoming increasingly important for the markets of non-renewable material.

Perhaps the trickiest issue in mineral policies is how to best invest the wealth and revenue generated by mining according to the principles of sustainable development. In addition to generating local sustainable benefits through infrastructure and economic diversification, mining revenues should be invested transparently in generating sustainable industries and productive capacities on the national level for long-term net benefits. In doing so, it makes sense to emphasise activities that contribute to sustainability in their own right, such as cleantech and energy technologies. This is also in line with the approach of Daly (1990), who suggested investing specifically in material substitution to compensate for the loss of natural capital due to mining.

One responsible way to invest the revenues from mining is to promote research and development in low impact exploration, mining, processing, environmental technologies, recycling, and substitution for the benefit future generations. New technologies not only reduce the impacts of mining but also make new deposits accessible and their beneficiation feasible, indirectly increasing the stock of deposits we leave behind for future use (e.g., Langefeld, 2017). We should continue accumulating geoscientific observations, developing geological, deposit, and geoenvironmental models, and investing in tailored environmental technologies for mining. Indeed, the EU and many of its member states have invested in research in the mineral sector and non-renewable raw materials through targeted research funding, greatly advancing sustainability in the raw materials sector.

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Riverbed aggregates dredging

Tamás Hámor and Gábor Kovács*

Dredging of aggregates, mainly sand and gravel, is a common practice in rivers and coastal marine settings, and less frequently also in lakes. The driver for this activity is usually two-fold: the extraction of raw materials for construction and the maintenance of waterways to ensure safe shipping, avoid bank erosion and prevent local flood risks. The major criticism usually made is that dredging disturbs aquatic ecosystems, destroys natural filter layers of potable water reserves, and may emit polluting substances. As a "flow-type" mineral commodity, the permitting and legislation issues can be complicated. In addition, sophisticated and high-resolution sediment re-charge supply models that would allow precise forecasts on the sustainability of this activity are scarce on both a local and river basin scale. This article addresses the above aspects of river dredging by providing a short review of the literature and legislation, and an assessment of its sustainability, using dredging in Hungary as an example of activity at the Member State level.

Le dragage d'agrégats, principalement de sable et de gravier, est une activité habituelle en zones de rivière et secteurs côtiers, plus rare en zone lacustre. Le moteur de cette activité est généralement double: l'extraction de matières premières pour la construction et la maintenance des voies d'eau pour garantir une navigation sécurisée, éviter l'érosion des berges et parer aux risques d'inondation locale. Le motif habituel de critique réside dans le fait que le dragage perturbe les écosystèmes aquatiques, détruit les filtres naturels des réserves d'eau potable et peut être à l'origine de substances polluantes. En tant que source potentielle de produits minéraux, l'obtention d'autorisations conformes au code minier peut être compliquée. De plus, les modèles sophistiqués et haute résolution concernant la recharge de sédiments, qui permettraient de prévoir avec précision les conditions de pérennité de cette activité, sont rares à l'échelle aussi bien locale que de bassin. Cet article traite des aspects évoqués ci-dessus de dragage en rivière, examine brièvement les volets littérature et législation, et, utilisant comme exemple le dragage en Hongrie, évalue la pérennité de cette activité au niveau de l'Etat.

El dragado de conglomerados, especialmente de arena y gravilla, es una práctica habitual en ríos, zonas costeras y, aunque con menor frecuencia, también en lagos. Normalmente esta actividad se realiza con dos finalidades: la extracción de materias primas para la construcción, y el mantenimiento de las vías navegables para así asegurar el transporte seguro, evitar la erosión fluvial y prevenir los riesgos de inundación local. La mayor crítica que recibe esta práctica es que altera el ecosistema acuático, destruye capas de filtrado natural de las reservas de agua potable, y puede emitir sustancias contaminantes. Debido a la peculiaridad del agua como producto mineral, los permisos y cuestiones legislativas pueden ser complicados. Además, modelos sofisticados de alta resolución y recarga de sedimentos que permitirían precisar predicciones sobre la sostenibilidad de esta actividad son escasas a nivel local y en cuencas fluviales. Este artículo recoge los aspectos previamente mencionados del drenaje de ríos ofreciendo un breve resumen de las publicaciones y la legislación, y una evaluación de su sostenibilidad, centrándose en el drenaje en Hungría, como ejemplo de actividad a nivel de estado miembro de la Unión Europea.

Introduction

Aggregates are granular materials used in construction. Primary aggregates are obtained by extraction from natural sources and include sand, gravel and crushed rock (Blengini *et al.*, 2012). Secondary aggregates are by-products from other industrial processes, like blast or electric furnace slags or china clay residues, mineral processing residues, or recycled aggregates derived from construction and demolition wastes. Aggregates are extracted from quarries, pits, and marine and fluvial dredging. In locations on land with a high groundwater table, aggregate extraction technology can also be achieved using vessel-based dredging, resulting in the formation of artificial lakes. An insignificant amount of aggregates may also originate from the removal and reworking of overburden sediments and rocks targeted at the extraction of other mineral commodities.

The aggregates sector is the largest amongst the non-energy extractive industries in Europe. The European aggregates demand is 2.7 billion t/year, 5 t/capita, representing a turnover of more than €15 billion. Eighty seven per cent of all aggregates produced are from quarries and pits. The aggregates industry comprises 15,000 companies (mostly SMEs) with 200,000 employees, operating in 26,000 sites (UEPG, 2018).

The share among the different aggregates is: 47 % crushed rock, 41 % sand and gravel, 8 % recycled aggregates from construction and demolition waste, 2 % from marine dredging, and 2 % manufactured aggregates (from slag and ash). Although no data are available on aggregates derived from

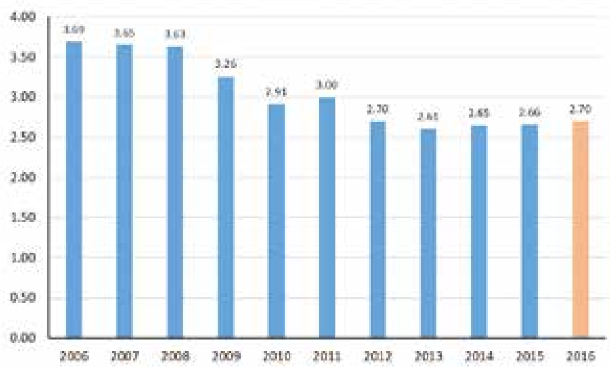

Figure 1: Aggregates production in the European Union and EFTA countries (in billions of tonnes) (UEPG, 2018)

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fluvial dredging, this source is estimated to represent less than 0.1 % of the overall output.

The correlation between economic performance (GDP) and the demand for aggregates is well documented, and attempts to decouple this, i.e. via resource efficiency and recycling, show no obvious results yet. In this respect, it is surprising that the aggregates production of the EU-EFTA countries shows a limited and delayed effect of the 2008 crisis, and slow recovery after 2013 (***Figure 1***).

Dredging is the removal of sediments from the bottom of water bodies (rivers, lakes, coastal marine areas). It is a routine necessity in waterways to offset the effects of silting – the natural sedimentation of sand, silt, clay and gravel. Environmental dredging is also applied for removing polluted sediments or non-polluted clay fractions that inhibit oxygenation and the transparency of water (Manap & Voulvoulis, 2016). Extraction involves a variety of technologies from cutter suction to bucket dredging, each with different efficiencies and impacts.

EU Community legislation

An analysis of the European Union Community legislation was presented in detail for the extractive industry in general (Hámor, 2004) and more specifically on aggregates sector (Hámor *et al.*, 2011). Recently, the Raw Materials Information System of the European Commission, developed by the Joint Research Centre, provided an updated review of the *acquis communautaire* (the accumulated legislation, legal acts, and court decisions which constitute the body of European Union law)[1] (Manfredi *et al.*, 2017). Based on a simple text search for dredging, the following provisions are the most relevant and specific in the *acquis*.

Dredging, as an economic activity, is listed in both the Directive on concession contracts (2014/23/EU) and the Directive on public procurement (2014/24/EU) with NACE code F 45.24 among "Construction of water projects". Directive 2017/2397/EU on recognition of professional qualifications in inland navigation considers dredging and its manoeuvres as a navigational operation, and acknowledges that floating equipment means a floating installation carrying working gear such as dredging equipment. In addition, Directive 2006/87/EC on laying down technical requirements for inland waterway vessels sets detailed provisions, e.g. on the stability of dredging vessels.

Regulation 2017/352/EU establishing a framework for the provision of port services and common rules on the financial transparency of ports provides a definition on dredging in ports: "the removal of sand, sediment or other substances from the bottom of the waterway access to the port, or within the port area that falls within the competence of the managing body of the port, including the disposal of the removed materials, in order to allow waterborne vessels to have access to the port; it comprises both the initial removal (capital dredging) and the maintenance dredging carried out in order to keep the waterway accessible, whilst not being a port service offered to the user".

The Environmental Impact Assessment Directive (2011/92/EU) classifies "extraction of minerals by marine and fluvial dredging" in Annex II 2. (b) as an activity for which Member States shall determine whether the project shall be made subject to an assessment. Member States shall make that determination through a case-by-case examination or thresholds (or criteria), or both procedures.

The most relevant part of the *acquis* is in relation to the Water Framework Directive (2000/60/EC), which sets a number of environmental objectives both for surface waters and groundwaters. While normally obliged to prevent inputs of pollutants, Member States can grant exemptions when, for instance, pollutants occur when intervening in surface waters to mitigate the effects of floods and droughts or for managing waters and waterways. These activities, which can include cutting, dredging, relocation and deposition of sediments in surface water, must be conducted in accordance with the regulations of the Member State. The exemptions may be used where the competent authorities have established an efficient monitoring system.

The Marine Strategy Framework Directive (2008/56/EC) and Commission Decision 2010/477/EU on criteria and methodological standards on good environmental status of marine waters are worth mentioning in the context of marine dredging. The EU Natura 2000 network is based on the Habitats Directive (92/43/EEC) and the Birds Directive (2009/147/EC). Local protected sites may represent a conflict to both marine and fluvial dredging.

Dredging generates hardly any waste and therefore the waste *acquis* is less relevant; nevertheless, the Extractive Waste Directive (2006/21/EC) and the European Waste Catalogue Chapter on Mining (Comm. Dec. 2001/118) are deemed applicable. This interpretation is backed by the fact that "spreading of … sludges from dredging", and "deposit of non-hazardous dredging sludges alongside small waterways from where they have been dredged out and of non-hazardous sludges in surface water including bed and subsoil" are excluded from the scope of the Landfill Directive (1999/31/EC).

Case law with regard to dredging, under the relevant jurisdictions of the European Court of Justice, mostly deals with state aid issues and concerns conflicts with the Natura 2000 sites (e.g. Cases C-226/08, C-461/13) and with interpretation of the Environmental Impact Assessment Directive.

Community policies and funded R&I projects

Since the Raw Materials Initiative was published in 2008[2], the safe supply of raw materials has been among the political priorities of the EU. Its second pillar on safeguarding domestic resources and supporting enhanced extraction is relevant to aggregates. However, fluvial dredging does not receive any specific attention.

Assessments of critical raw materials for the EU economy[3] included aggregates in the scope of the assessment. Although the calculated supply risk exceeded the threshold for criticality, the economic importance was below the threshold, and therefore aggregates were not categorised as critical raw materials.

In many locations it is a challenge to ensure compatibility of dredging with Natura 2000 and the corresponding environmental management. Across Member States there is a difference in interpretation of directives that relate to Natura 2000. This is reported to thwart the EU single market, as reflected in numerous European Court of Justice judgments. In 2011 the European Commission published a Guidance Document on non-energy mineral extraction and Natura 2000[4], where marine dredging is presented in detail. The lack of references on riverbed dredging either indicate the minor weight of this activity in the supply mix or the insignificant number

1 ***http://rmis.jrc.ec.europa.eu/?page=eu-community-secondary-law-6b713d***

2 ***http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1466412882018&uri=CELEX:52008DC0699***

3 ***http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1466426043300&uri=CELEX:52014DC0297, http://rmis.jrc.ec.europa.eu/?page=crm-list-2017-09abb4***

4 ***http://ec.europa.eu/environment/nature/natura2000/management/docs/neei_n2000_guidance.pdf***

of cases conflicting with nature conservation. River dredging is only mentioned in one case, the Cliffe Pools case (UK) where sand and gravel dredged from a nearby riverbed were used to backfill former clay pit impoundments later flooded by saline water.

Dredging is almost completely missing as a theme in any of the EU FP7 and H2020 calls and projects, as determined from a review of the list of raw materials related research projects recently published by the ORAMA consortium[5]. The ERDF Interreg project "Danube Sediment"[6] represents one of the very few exceptions. It calls for the sustainable sediment balance management of the river, also with a view to dredging (Maier & Skiba, 2017). The EC Joint Research Centre recently published a study also dealing with these issues (Vigiak *et al.*, 2017).

Aggregates and dredging in Hungary

Hungary is used here as an example of a land-locked Member State where river dredging is a minor but existing aggregate production activity.

The framework conditions

In compliance with the provisions of the Water Framework Directive, the River Basin Management Plan of Hungary was published and approved by the European Commission in 2012[7]. Hungary is a land-locked country which covers a significant part of the downstream section of the Danube River Basin. The Plan has very few references to dredging: It presents dredging as an environmental pressure due to the physical modification on river and lake water bodies that are reduced or modified because of the hydromorphological impacts of dredging. This statement is based on a detailed survey on hydromorphological alterations of all surface waters between 2006 and 2008. In engineering activities, including dredging, it is unclear what tools were applied to define their level of significance, as only the number of water bodies affected was provided.

The national legislation in Hungary on dredging in relation to environmental management and water quality is similar to the Community law (European Commission, 2017). The thematic scope of the national legislation covers rules on fiscal instruments, pollution thresholds, and technical details on water works.

The national Mining Act is also applicable for dredging (Szabados & Hámor, 2010). Where the primary objective of dredging is aggregate extraction, an exploration permit, a mineral reserves report, the establishment of a mining plot and an extraction technical operation plan are the major requirements. This permitting process may take 2-3 years. When aggregates dredging is a collateral activity to water works primarily directed at improving navigation ways, flood prevention, etc., the permit is issued under the scope of the Water Act[8].

Both primary mining by dredging and collateral production as part of water works activity are incorporated into the sphere of authority of the so-called County Government Offices, which are typical one-stop-shop permitting entities. Either ways, the dredging company must pay a mining royalty based on the volume of aggregate extracted; this feeds into the central state budget. Therefore, local municipalities, which also have a role in permitting as an invited co-authority, have no particular interest in supporting this activity.

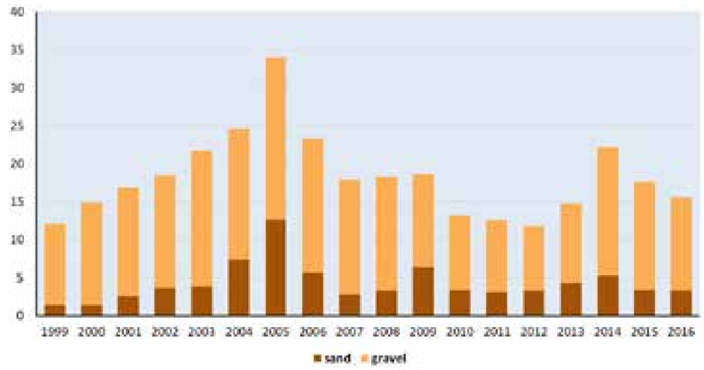

Figure 2: Extraction of aggregates in Hungary, 1999-2016 (in million m3) (MBFSZ, 2018).

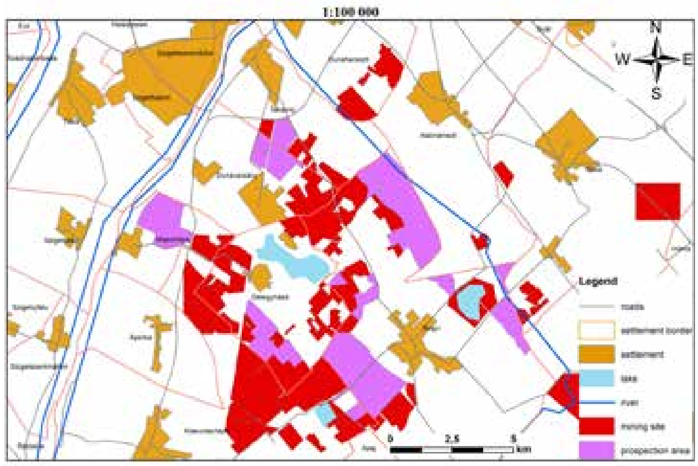

Figure 3: Current and past aggregates extraction on the Csepel Plain, 10 km south of Budapest.

Production, environmental pressures

Hungary covers the major, central part of the Pannonian Basin (the Carpathian Basin in geographical terms). As a depositional center of sediments, it has significant resources and reserves of fossil (Quaternary and Holocene) river terrace gravel and sand. The location of these reserves are along the current and paleo riverbed lines of the Danube, Tisza, Dráva, Maros, Hernád and Sajó rivers, and along the forelands of the Mátra and Bükk mountains in the Northeast.

The production of the Hungarian mining industry was more than 52.9 million tonnes in 2011, of which 75% was non-metalliferous mineral raw material. The growing significance of non-metalliferous mineral raw materials is reflected by the fact that their proportion grew (84% in 2014). According to the national inventory (MBFSZ 2018) as of 2017, there were 513 registered aggregates mining plots covering ca. 218 km^2, representing 0.2% of the territory of Hungary. Over time, aggregates extraction in Hungary (***Figure 2***) does not match the EU curve. For example, the effect

5 ***https://orama-h2020.eu/downloads/#Deliverables***
6 ***http://www.interreg-danube.eu/approved-projects/danubesediment***
7 ***http://eur-lex.europa.eu/legal-content/EN/TXT/DOC/?uri=CELEX:52012SC0379&rid=24***
8 ***http://rmis.jrc.ec.europa.eu/uploads/cpro-files/MINLEX_CountryReport_HU.pdf***

of the 2008 crisis was delayed by one year, and the 2014 positive peak was most likely driven by the infrastructure developments financed by the EU funds. Companies are active in exploration, too; there are 154 licensed exploration plots for aggregates, covering 308 km^2.

Many of the side effects of aggregates extraction in open pits are present on the Csepel Plain (***Figure 3***), located south of Budapest, which provides the majority of supply demanded by construction in the capital city. Situated on the Danube terrace, most of the extraction is performed below the groundwater level via dredging; as a result, these sites are principally lakes with dredging technologies. The evaporation of open water has led to a remarkable fall in groundwater levels in the wider region. The change in land use is also significant: the total area of the involved settlements is 615 km^2, of which 45 km^2 is covered by the mining plots, representing 7 % of the area. It is unlikely that many former pits can be returned to previous types of land use. Conflict with locally protected Natura 2000 sites does occur.

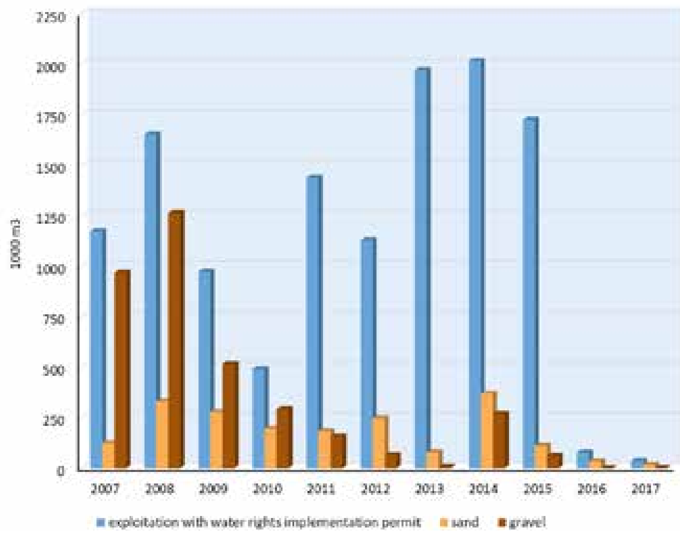

Figure 4: Aggregates production due to water rights and sand and gravel volumes of riverbed dredging in Hungary.

Riverbed dredging

Riverbed dredging has long traditions in Hungary, being in use since the mid-19th century. At that time gravel production originated mostly from the Danube and the gravel quarry-lakes. The heydays of industrial dredging were in the 1970-80s, when the production was in the scale of millions of cubic metres annually. During the last 20 years dredging output dropped significantly due to several factors, including a more stringent legal regime, expanding nature conservation, dams built upstream, the transition to a market economy and the enhanced competition from other supply sources. At present, sand and gravel extraction by dredging is on the order of a few thousand m^3 annually (***Figure 4***). The ratio of the extracted bulk volumes with the water authority permit (shown in blue in ***Figure 4***) versus gravel sold and delivered indicates that bi-product production arising from waterworks activity is far greater than primary production. This raises the question of how the missing material volume is managed in an environmentally responsible manner.

Concerning technology, some dredging sites are more reminiscent of artisanal and small-scale mining (ASM) sites outside Europe than of an industrial extraction site (***Figure 5***). Good practice sand dredging is being carried out on the Maros (Mureș) River, where 4–5 dredging river sections operate 5 to 10 km apart. As a result of this dredging, high quality plaster sand is obtained. Despite dredging for many decades along the same stretch of the river, the water authority has not reported any negative impact on the river bed or aquatic wildlife.

Sustainability issues

Dredging has numerous advantages and positive environmental effects, such as *(a)* the extraction of raw materials for construction, *(b)* maintenance and order of waterways to ensure safe shipping and to avoid river bank erosion, *(c)* preventing and mitigating local flood risks, *(d)* removal of polluted anthropogenic sediments, and *(e)* improving water quality and living conditions for benthic fauna by removing fine sediments to help oxygenation and avoid eutrophication. Wet extracted aggregate material has a higher quality; it is already washed, thus has better granulometric grading. The most frequently cited criticism of dredging is that it may disturb aquatic ecosystems. However, as an example to the contrary, very rapid recovery of the fauna was observed after the Baia Mare cyanide spill (BMTF Report 2000). Dredging may also destroy natural filtering layers for potable water reserves, and may emit polluting substances (engine fuels, lubricants, exhaust gases). These impacts need to be assessed and evaluated in a balanced way against the advantages of dredging at both the local and regional scale in a river basin.

Furthermore, if comparing extraction and dredging based on their effects on the environment (***Table 1***) river dredging is advantageous. There is no negligible difference in the fact that the extracted mineral raw material in the riverbeds re-charge from time to time, which does not occur in quarries or pits.

Conclusions

Responsible fluvial dredging in land-locked continental settings may contribute to a more sustainable mix of aggregate supply, better ecological status of water ecosystems and water quality, and maintaining waterways. The proposal of minimum conditions as a list of baseline measures for responsible dredging are: *(a)* good governance in a broad sense that involves *(aa)* clear national legislation, *(ab)* streamlined permitting, *(ac)* favourable financial framework, and *(ad)* a better co-operation

Figure 5: Dredging technology on the Maros River.

of the competent authorities; *(b)* smart spatial development and land use planning at regional and local scale which is supported by *(c)* modelling the sedimentary balance of rivers in the river basin management plans that can also feed in to *(d)* complex sustainability assessments in addition to conventional environmental impact statements. It is understood that dredging cannot replace aggregate quarrying but it can be a good example that is sustainable and contributes to developing circular economy. Systematic data collection and river basin scale assessment models are needed for better established conclusions which may aid decision-makers engaged in considering sustainability issues in this specific sub-sector of the extractive industry.

Table 1: Environmental impact matrix of the mining activities (- Low damage, - - Moderate damage, - - - High damage, 0 Neutral impact, + Positive impact).

	extraction from quarry	riverbed dredging
soil	- - -	0
mineral raw material	- - -	- -
bedrock	-	0
surface water	-	- -
groundwater	- - -	- -
subsurface water	- -	-
aquifier	- -	-
air quality	- -	- -
noise, vibration	- -	- - -
flora	- - -	- -
fauna	- -	-
land use	- - -	+
landscape, visibility	- - -	- / 0

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A proposal for ecological and geological monitoring of mining enterprises in the Far Eastern region of Russia

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Eco-geological monitoring (a system of permanent observations) of natural, geological and anthropogenic changes is crucial for the sustainable development of mining areas and enterprises. At the same time, it is necessary to take into account the specific features of the impact of the anthropogenic system of the mining enterprise on the environment, the background state of the environment in the given territory, other available anthropogenic sources of this impact, the existing monitoring system, the composition of the pollutants, and the peculiarities of the natural conditions which determine the distribution and accumulation of pollutants. This paper proposes a methodological approach to eco-geological monitoring through development of a monitoring system in the zone of influence of mining enterprises.

Le suivi éco-géologique (un système d'observations en continu) des changements naturels, géologiques et d'activités humaines, est crucial pour le développement durable des zones minières et entreprises concernées. En même temps, il est nécessaire de prendre en compte les éléments spécifiques caractérisant l'impact industriel et humain des entreprises minières sur l'environnement, l'arrière-plan environnemental d'un territoire donné, les autres causes d'impact connues et touchant les interventions humaines, le système actuel de contrôle, la composition des polluants et les particularités des conditions naturelles qui conditionnent la dissémination et l'accumulation des polluants. Cet article propose une approche méthodologique de suivi éco-géologique à travers le développement d'un système de contrôle dans la zone touchée par les activités d'entreprises minières.

La monitorización eco-geológica (un sistema de observación permanente) de cambios naturales, geológicos y antropogénicos es crucial para el desarrollo sostenible de las áreas de minería y para las empresas. Al mismo tiempo, es necesario tener en cuenta las características específicas del impacto del sistema antropogénico de las empresas mineras en el medio ambiente, el estado del medio ambiente en el territorio, otras fuentes antropogénicas de este impacto, los sistemas de monitorización existentes, la composición de las sustancias contaminantes y las peculiaridades de las condiciones naturales que determinan la distribución y acumulación de las sustancias contaminantes. Este artículo propone un enfoque metodológico para la monitorización eco-geológica mediante el desarrollo de un sistema de monitorización en la zona de influencia de las empresas mineras.

Introduction

The Far Eastern Federal District is 6,215,900 square kilometres, 36.4% of the territory of Russia (***Figure 1***). The population of the region is 6,293,100 people (4.9% of the population of Russia). The centre of the Far East is Khabarovsk.

The vast majority of the mining enterprises in this region were created more than 30 years ago. In recent years, the number of new discoveries has declined sharply, along with a reduction in geological exploration due to financial reasons. The process of augmenting the mineral resource base (MRB) has decreased. Some examples: diamond reserves decreased by 7% in 2016 compared to 2011, platinum by 18%, tin by 4%, etc. The mining industry in the region has suffered considerable damage (there was a reduction in production). A negative

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Figure 1: Far Eastern Federal District on the map of Russia.

balance of stock (resources) has been noted in recent years (i.e. the stock has decreased): for placer gold, coal, copper, lead, zinc, nickel, cobalt, tin, antimony, boron ores, fluorspar, silver, platinum, etc.

Now the region occupies a leading position in the country in geological prospecting and licensing. The mineral resources of the Far Eastern Federal District (DFO) predetermine the possibility of a significant increase in gross regional product (Sklyarova & Arkhipova, 2011). The main products of the mining industry of the Far Eastern region of Russia are fossil fuels (oil, gas, coal), precious metals (gold, silver, platinum) and precious stones (diamonds), nonferrous metals (tin, tungsten, lead, zinc) and nonmetallic minerals (boron, fluorite) (***Figure 2***).

Currently, more than 50 companies work in the Far Eastern region or participate in the management and capital of enterprises involved in the development of ore deposits: Russian, Russian with shares of foreign capital, or joint ventures. The largest of them, as well as the deposits that they develop, the type of minerals and the regions of the Far Eastern Federal District, in which the deposits are being developed, are shown in ***Table 1***.

The table shows that trans-regional and large companies are the main exploiters in the (see Arkhipov, 2015, for a location map). Several corporations have also been created to manage the development of territories, with founders in the form of state authorities. However, the deposits are located on a territory of considerable size. The already acquired areas of activity of the largest companies are territorially more or less disconnected, which is natural for the mining industry in general, but especially for the Far Eastern region (see ***Figure 2***).

The mining companies listed above undoubtedly cause irreparable harm to the environment (Krupskaya *et al.*, 2017). To improve the situation, a system of constant monitoring of the environmental situation within the mining territory is required, namely, environmental and geological monitoring.

Figure 2: Some large deposits of the Far Eastern Federal District. Compiled by Arkhipov & Arkhipova.

Eco-geological monitoring

The object of eco-geological monitoring is the geological environment and the impact processes on the ecological environment of the surrounding nature. So, for example, the eco-geological monitoring of the Far Eastern region of Russia reflects the specific anthropogenic load on that territory. Monitoring of the state of the environment is carried out in accordance with the Resolution of the Government of the Russian Federation "About the Establishment of the Unified State System of Environmental Monitoring" of 24 November 1993. Environmental problems arising from the extraction of mineral raw materials are handled by the following authorities: Ministry of Natural Resources of the Russian Federation; State control service in the sphere of nature management and environmental safety; State Environmental Protection Service; Federal Service of Russia for Hydrometeorology and Environmental Monitoring and other services.

In this relation, there is a need to create and develop a monitoring system in the zone of effect of the mining companies, to ensure environmental safety and a rational use of the natural resource potential, and to implement in practice the principles of sustainable development of the region.

When organising such monitoring, the observation network should be aimed at monitoring surface water and groundwater (hydrodynamic regime and chemical composition of water); possible types of pollution of soils, vegetation and rocks; the aerosol component of the air environment; and the stability of the fronts of open-cast mines and tips.

Practical organisation of environmental and geological monitoring, as well as other types of monitoring, should be based on a methodological and methodical basis in the form of a targeted integrated program. At the same time, it is often proposed to compile such programs by analogy with territorial complex schemes (TCS) (Imethenov *et al.*, 2001). In this regard, the three conceptual principles of TCS are highlighted: a systematic, integrated and program-targeted approach. Systematic and integrated: the programs of eco-geological monitoring imply consideration of monitoring objects within a single geological environment, which in turn is part of the overall environment in the natural, technical and social aspects. According to these principles, the program should be based on the conceptual ecological foundations of sustainable development of territories, in which the main role is played by:

- Priority of quality indicators (quality of life) over quantitative indicators;
- Preservation of biodiversity and cultural values;
- Priority of the sustainability of the development over maximum economic profit.

In all environmental and geological monitoring, anthropogenic changes and damage to all natural and technical objects and the population in aggregate should be analysed.

Ways and methods of practical implementation of the target complex program

Table 1: Mineral Resources of the Far Eastern region of Russia.

Minerals	Main companies	Region, Region, District	Some deposits
Gold, silver, polymetals	Polimetall	Magadan region, Khabarovsk region, Chukotka Autonomous District	Lunnoe, Dal'nee, Dukat, Pereval'noe;Hakandzhinskoe, Yur'evskoe, Kutynskre, Svetloe; Majskoe, Klen and others
Gold, ferrous metals	Petropavlovsk PLC	Amur Region, Jewish Autonomous Region	Pokrovskoe, Pioner, Kuranahskoe; Kimkanskoe, Sutar-skoe, Kosten'ginskoe and others
Gold, silver	Group Polyus Gold, Seligdar	Magadan region, Republic of Sakha (Yakutia), Amur region	Natalkinskoe, Tokichan; Nadezhda, Ryabinovskoe, Mezhsopochnoe, Podgolichnoe; Malomyrskoe, Burindinskoe and others
Precious metals	Alliance group, Artel of gold prospectors Amur, Amur Zoloto	Khabarovsk region	Ozernoe, Kirankan, Tas-Yuryah, Kondyor, Durminskoe and others
Gold, silver	Renova Group, Berkley Investments, Kamgold, Zoloto Kamchatki	Kamchatsky region	Shanuch, Lazurnoe, Dranka, Kumroch and others
Gold, silver	Nordgold	The Republic of Sakha (Yakutia), Amur region	Tabornoe, Gross, Prognoz; Berezitovoe and others
Gold, silver	GDK Sibir', Bazovye ehlementy	Chukotka Autonomous District	Kekura, Kupol, Dvojnoe and others
Polymetals	GMK Dal'polimetall	Primorsky region	Nikolaevskoe, Smirnovskoe, Majminovskoe, Yuzhnoe, Malinovskoe, Silinskoe, Lazurnoe and others
Fluorspar	Rusal, YAroslavskaya GRK	Primorsky region	Pogranichnoe, Voznesenka-2
Boron	GHK Bor	Primorsky region	Dal'negorskoe
Gold, silver	Severnye priiski	Magadan region, Primorsky region	Matrosovskoe, Dzhul'etta, Zatesnoe; Krinichnoe, Pervomajskoe
Gold	IK Arlan	Magadan region	Pavlik, Rodionovskoe, Utinskoe, Shah, Burhala
Gold, uranium	Tekhsnabehksport, Uranovyj holding Atomredmetzoloto	Republic of Sakha (Yakutia)	Ehl'konskoe, Lunnoe
Polymetals	Geopromajning	Republic of Sakha (Yakutia)	Verhne Menkeche, Sarylahskoe, Sentachan
Ferrous metals	AK Alrosa, GMK Timir, Evraz	Republic of Sakha (Yakutia)	Tayozhnoe, Desovskoe, Tarrynahskoe, Gorkitskoe
Gold, silver, polymetals	Geotekhnologiya	Kamchatsky region	Kuvalorogskoe, Kvinum, Dukukskoe, Shanuch, Kumroch

are related to the third principle, on the basis of which the program should have a scientific justification: the selection of specific areas and objects of the real and expected anthropogenic change in natural objects; the choice of a methodical monitoring system, the establishment of an observational network, the regime and the observation period, taking into account already existing regime observations.

The spatial boundaries of the eco-geological monitoring and the location of the observation points of the fixed network are determined by the content of the tasks to be solved during the monitoring, the peculiarities of the natural situation, migration routes, and accumulation and removal of pollution from the anthropogenic object to the environment.

An example of the organisation of regional environmental monitoring in the south of the Far East is shown in ***Figure 3*** (Saksin & Bubnova, 2007). The ecology-forecast map of the regions of extraction of non-ferrous and rare metals in the southern part of the Far East was designed by Mining Institute FEB RAS. The regional natural-mining systems and the points of observation of the state of the surface water are marked on the map. Data of observation for the organisation of the first stage of regional environmental monitoring was collected by Roshydromet, the Ministry of Natural Resources of Russia and water users.

The map shows existing and potential regional natural-technical systems within which it is advisable to conduct more detailed and more labour-intensive scientific research in order to assess the environmental risk of development. The method of constructing the map is based on the following principles:

- Zonality of the structure of halos of pollution formed around mining enterprises;
- Limit estimates of external borders of zones;
- Basin organisation of streams of substance and energy;
- Accounting for the main natural factors of migration of heavy metals at the local level.

The map consists of 3 interconnected blocks. The first two deliver data for solving the main tasks of the third block:

- Definition of a geographical location and probable borders of the predicted rank objects in the ore area, area and the province;
- Scores of the environmental risk of the development of these facilities.

Along with the regional natural and mining systems, the main elements of the generalized model of migration of pollutants from the continent are shown. This allows us to give scientific recommendations for the location of environmental monitoring points for monitoring the development of functioning regional natural and mining systems.

When developing environmental-geological monitoring, the following tasks must be carried out: 1) justifying the rational placement of a network of monitoring points, based on the basin principle of migration of matter and energy from the continent; 2) determining the objects of testing and controlled parameters, linking the technology used to the mineralogical and geochemical features of the studied raw materials and the natural conditions of the formation of man-made flows; 3) determining the necessary

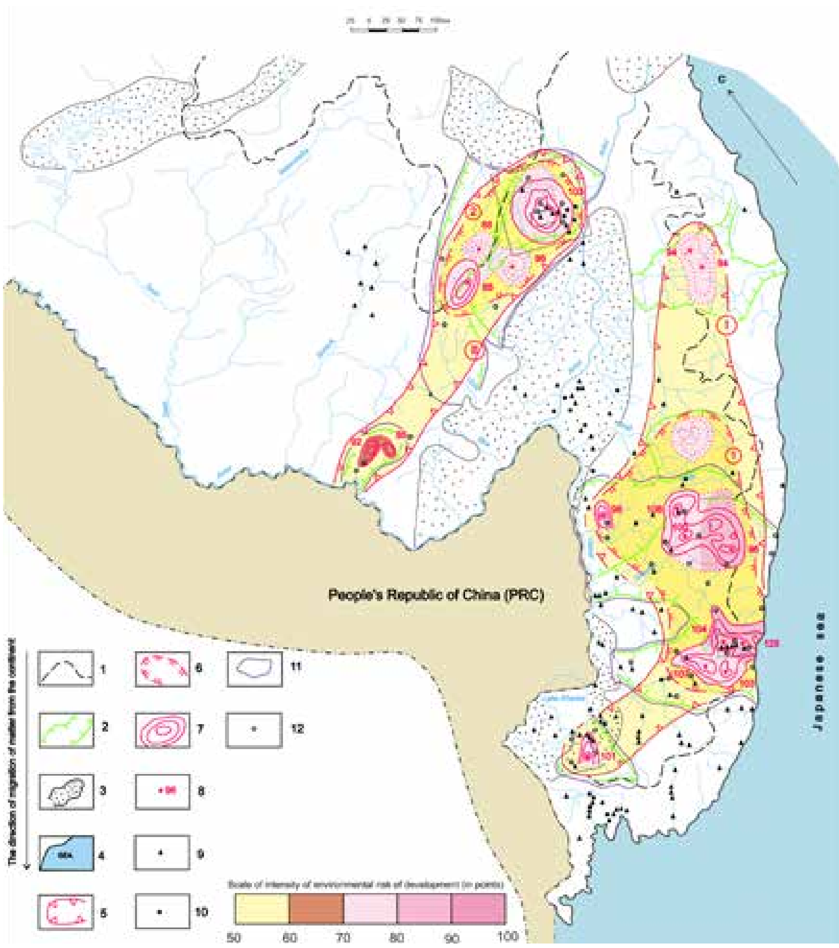

Figure 3: Ecological forecast map of the areas of extraction of nonferrous and rare metals in the southern part of the Far East of Russia. From Saksin & Bubnova (2007).

1-4 - The main elements of a generalised model for the migration of pollutants from the continent: 1 - regional watersheds that outline the catchment areas of the seas and trans-regional rivers; 2 - large river basins draining existing and possible natural and mining systems in the future; 3 - continental (intermediate) basins of accumulation; 4 - marine sedimentary basins.
5-8 - Regional natural and mining systems (projected): 5 - provinces (I - Primorskaya, II - Khingano-Badzhalskaya); 6 - areas (1 - Ussuri-Bikinskaya, 2 - Komsomolsko- Badzhalskaya); 7 - areas - the limiting position of the outer boundaries of the 1st, 2nd and 3rd contamination zones is shown as continuous, and the dotted line is their probable position after the development of the State working balances; 8 - maximum assessment (in points) of the environmental risk of developing the field in the circuit.
9-12 - Control over the development of regional pollution: 9-10 - observation points for surface water: 9 - Roshydromet, 10 - MNR of Russia and water users; 11-12 - objects of mining and environmental monitoring (recommended): 11 - contours of areas where it is necessary to organise regional mining and environmental monitoring; 12 - points of regional mining and environmental monitoring.

frequency of testing various components of the natural environment; 4) justifying the types of analytical studies.

As sampling objectives, it is recommended, to use soils in addition to surface waters as the main environmental targets that can hold various types of pollution and perform both a buffer and a detoxicant role, as well as bottom sediments, sediments of local watercourses formed in conditions of active water exchange, possessing high ability to accumulate many chemical toxic elements.

The impact of toxic waste from mining enterprises on the ecosphere can be estimated and forecast also on the basis of modern information technologies that allow the processing and analysis of large amounts of diverse information (Potapov *et al.,* 2005). The analysis of constantly updated spatial data obtained directly from mining enterprises is possible when creating an information system for environmental and geological monitoring, which consists of the regulated collection, storage and subsequent processing of a huge amount of heterogeneous information, including materials of remote sensing of the Earth (RSE) from outer space.

The advantages of remote methods of studying the earth's surface in comparison with traditional ones are the scale of the survey and the possibility of obtaining global and local information about natural objects, as well as controlling the dynamics of online processes. Working with information in real time meant the application of remote sensing for the solving of environmental monitoring problems. Global information systems (GISs) are integrated software environments for working with a map, and in a broader sense with any spatially-spread and geographically-related data. Satellite data of the Earth allow us to tackle a wide range of problems in monitoring the natural environment (Kudashev & Filonov, 2005):

- Determination of meteorological characteristics, vertical temperature profiles, integral humidity characteristics, cloudiness, etc.
- Monitoring the dynamics of atmospheric fronts, hurricanes, obtaining maps of major natural disasters;
- Determination of the temperature of the underlying surface, operational control and classification of soil and water surface contamination;
- Detection of large or permanent emissions of industrial enterprises;
- Control of anthropogenic influence on forest park zones;
- Detection of large fires and the release of fire danger zones in forests, the detection of thermal anomalies and thermal emissions of large industries and CHP in megacities;
- Registration of smoky plumes from pipes;
- Monitoring and forecasting of seasonal floods and river spills;
- Detection and assessment of large flood zones;
- Control of snow cover dynamics and snow cover contamination in the zones of influence of industrial enterprises.

The monitoring system is based on the use of such data; therefore, its construction on the basis of GIS is justified, especially since the modern GIS is not only a means of processing of spatial data, but also a means of providing, developing and supporting the adoption of scientifically sound management decisions.

The strategy of sustainable development provides for an assessment of the degree to which the ecological endurance of a certain territory corresponds to anthropogenic impact and predicts the consequences of human intervention in the biospheric circulation of matter and energy. Diagnosis of the state of the ecosphere is the establishment and study of the characteristics characterising the state of the ecosphere, to predict possible deviations and disturbances in their functioning. At the same time, vegetation is a reliable indicator of the state of ecosystems and the degree of their transformation as a result of some impact (Kapitza & Rice, 2003). Comparison of the results of remote sensing with field research data makes it possible to improve the accuracy of the studies carried out.

Conclusion

In conclusion, the results of studies conducted on the example of mining enterprises of the Far Eastern region of Russia (carried out at some mining enterprises) have shown that a system of environmental and geological monitoring of the environment is the most rapid means of assessing the environmental impact of man-made activities in different natural conditions of the region Thus, it has been established that it is necessary to carry out monitoring that must take into account the specific features of the impact of the man-made system on the environment of the mining enterprise, the background state of the environment in the area, other available man-made sources of this influence, the existing monitoring system, the composition of pollutants and accumulation of pollutants. The use of remote sensing tools provides up-to-date, complete and reliable information on the degree of geological, hydrogeological, engineering-geological and ecological study of the area, and this, in combination with information from other sources and materials obtained under field conditions, is an effective mechanism for solving a wide range of both practical problems and theoretical studies.

To improve the environmental situation, a methodological approach is proposed for the development of a monitoring system in the zone of influence of mining enterprises. Ways for practical realisation are offered to tackle the problem of minimising anthropogenic changes in the region.

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Sustainable development of low population density regions – the Lithium Project in Guarda (Portugal)

A.M. Antão and A. Carolino*

Societal concerns with environmental questions and sustainability are priority issues; the exploitation of lithium cannot be carried out without considering environmental issues. The H2020 (IC&DT) Project LÍTIO is a joint project between a mining company, three polytechnics and the national professional association of geologists intended to create value for natural endogenous resources associated with territorial innovation in the mining district of Gonçalo. Its aims are preservation and sustainability of lithium through the development of a product, processes and services, environmental monitoring and innovative proposals for regional tourism promoting the mining area.

Les affaires sociétales avec questions environnementales représentent des thèmes prioritaires; l'exploitation du lithium ne peut pas fonctionner sans tenir compte du volet environnemental. Le Projet H2020 (IC&DT) LITHIO est un projet commun à une compagnie minière, trois Entreprises polytechniques et à l'Association Nationale des géologues professionnels, avec l'intention de valoriser les ressources naturelles endogènes, associées aux activités territoriales innovantes dans le secteur minier de Gonçalo. Ses objectifs sont la préservation et la pérennité du lithium à travers le développement d'un produit, de procédés et de services spécifiques, d'un suivi environnemental et de propositions innovantes dans le cadre de la promotion du tourisme régional dans cette région minière.

La preocupación social respecto a las cuestiones medioambientales y la sostenibilidad son cuestiones prioritarias: la explotación del litio no se puede realizar sin tener en cuenta los aspectos medio ambientales. LÍTIO, un proyecto de Horizonte 2020 (Investigación Científica y Desarrollo Tecnológico), es un proyecto conjunto en el que participan tres escuelas politécnicas y la asociación nacional de geólogos y que tiene como objetivo crear valor para los recursos endógenos asociados con innovación territorial en el distrito minero de Gonçalo. Sus objetivos son la preservación y la sostenibilidad del litio a través del desarrollo del producto, procesos y servicios, monitorización medio ambiental y propuestas innovadoras para promocionar el turismo regional en esta zona minera.

Introduction

Lithium is an alkaline metal with the atomic number three. It is the lightest metal on Earth, as well as the least dense solid element. Lithium is a rare metal in the Earth's crust and never occurs freely in nature. Its main sources are the minerals lepidolite, petalite, amblygonite, zinnwaldite and spodumene. Lithium is commercialised as a concentrated mineral in various chemical compounds (particularly in the form of carbonate or hydroxide). Lithium applications are increasingly diverse: it is used in ceramic and glass production, metallurgy of aluminium, manufacture of synthetic rubber and of lubricants, the process of purification of air in confined environments, in batteries as lithium bromide, and as lithium carbonate it is used in the pharmaceutical industry for the treatment of depression. With the increase in demand, and the consequent rise in the price of lithium, especially of the compounds used in the manufacture of lithium batteries, lithium carbonate and lithium hydroxide, pegmatite deposits are becoming cost-effective sources of lithium. After having secured the best pegmatite deposits in their countries, Australian and Canadian prospecting and

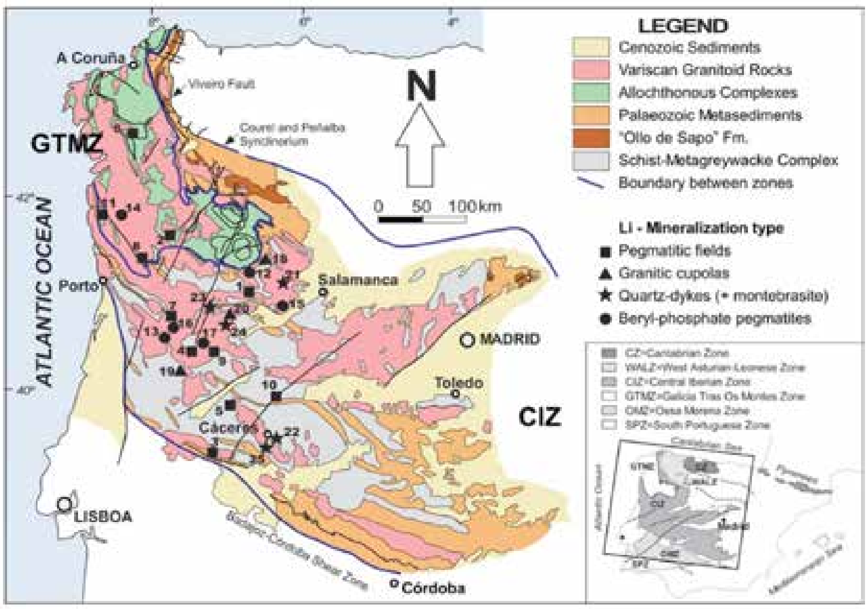

Figure 1: Schematic geological map of the Central Iberian Zone (CIZ) and the Galicia-Trás-os-Montes Zone (GTMZ), with the location of the different Li mineralisation areas of Iberia (4- C57 Mine Concession). (from Roda-Robles et al. *2016, p. 105).*

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research companies (P&R) began the study of other deposits of lithiniferous pegmatites occurring in Europe and particularly in Portugal, which is one of their P&R bases. The year 2016 was a year of excellence in the emergence of numerous 'young companies' around the world that together with traditional industrial companies operated not only from hard rock, but also from lithium exploration of salar brines. In 2017 Portugal ranked in sixth place worldwide and first in Europe in the mining production of lithium (USGS, 2018).

Lithium in Portugal

One of the largest lithium deposits belts in Europe is located on the Iberian Peninsula (***Figure 1***). These deposits are essentially lithiniferous pegmatite bodies that outcrop in metasedimentary rocks and granitoids of Variscan ages, along a zone of NNW-SSE direction in Galicia-Trás-os-Montes Zone (GTMZ) and Central Iberian Zone (CIZ) (Roda-Robles *et al.*, 2018; Farinha Ramos, 2007). The National Government, aware of the potential existing in the country, announced the establishment of a working group at the end of 2016 (Declaration No. 15040/2016 of 13 December 2016), with the mission to identify and characterise all of the lithium deposits in Portugal, as well as to evaluate the possibilities of their prospecting and exploitation. This group produced a final report in March 2017 (Report, 2017), which identified nine geological zones with lithiniferous potential in Portugal (***Figure 2***).

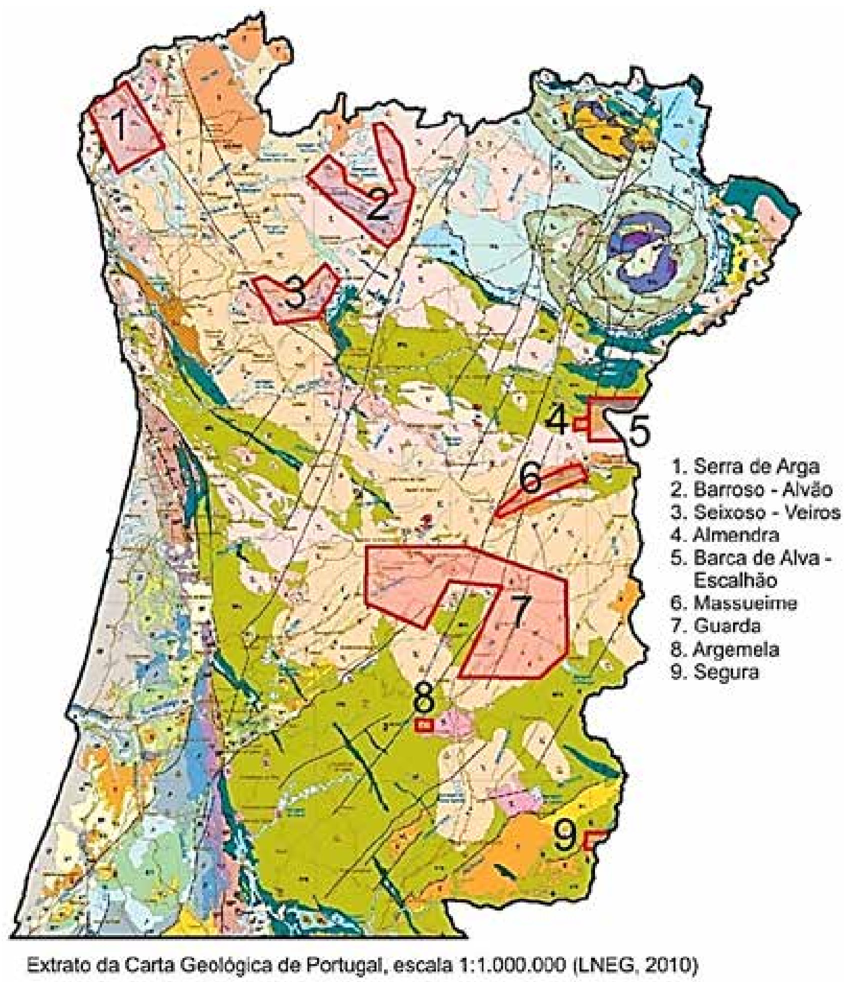

Figure 2: Formations with lithiniferous potential in Portugal (Report of lithium working group, available online at ***http://www.lneg.pt/divulgacao/noticias-institucionais/535****).*

The Gonçalo mining field

The C-57 mine is located within a rare aplite pegmatite field that outcrops in the Central Eastern region of Portugal. Lithiniferous veins are embedded in the facies of the Guarda porphyroid granite (Antão, 2004), as well as in the surrounding metasedimentary rocks (Roda-Robles *et al.*, 2016; Freitas *et al.*, 2015). The veins exhibit an aplite pegmatite structure consistent with the other sills in the Gonçalo mining field (location 4 in ***Figure 1***), with a main composition of quartz, feldspars and muscovite ± Li, Be, Nb, Ta and Sn minerals (Farinha Ramos *et al.*, 2006). The veins are usually sub-horizontal or with slight inclination of less than 15° and thicknesses about 3.5 m, which permits the open pit exploration of the mine. The mining field is crossed-cut by several late-hercynian faults that structurally control the pegmatitic field.

The C-57 mine has been in operation for several decades, mainly in the traditional supply of Li feldspar used by the ceramic companies in the central Portugal region. This product (Li feldspar) allows a significant reduction in the energy consumption during the fabric process of the ceramic industry. As a small mine company, C-57 mine works most of the time with outsourcing services for its mining processes.

The Gaia valley, where the Gonçalo mining area is located, has been an extensive mining field of tin, gold and now Li feldspar since Roman times and mainly from the beginning of the 20th century, and its exploitation caused serious environmental impacts with very aggressive repercussions in the local communities (Silva, 2015). One of the objectives of this project is to strengthen the appeal of this area for tourism and leisure activities, thus enhancing the mining heritage of this region. For this, the support of the local population is essential. The concerns of local communities with respect to environmental issues and sustainability are priority issues affecting the exploitation of raw materials (in this case lithium), unless it can be proven that it can be carried out without significant environmental impacts. Each region must take advantage of its natural resources, and in particular its geological endogenous resources, especially when they are specific to those localities. Many of the Portuguese geological resources are in less-favoured areas of the territory, most of them away from the great urban centres.

The H2020 IC&DT – LÍTIO Project

The recently approved IC&DT Project 023720 (LÍTIO Project), submitted through AAC/02/SAICT/2016, will allow the realisation of a set of activities for the enhancement of natural endogenous resources and territorial innovation in Gonçalo (Guarda County, Portugal). The LÍTIO Project has received a grant from the Portuguese government for a period of 18 months, which is the Portuguese state contribution in the co-financed H2020 EU project. It is a joint project among the C-57 mining company (Pegmatítica -Soc. Mineira de Pegmatites, Lda.), the three polytechnical higher edu-

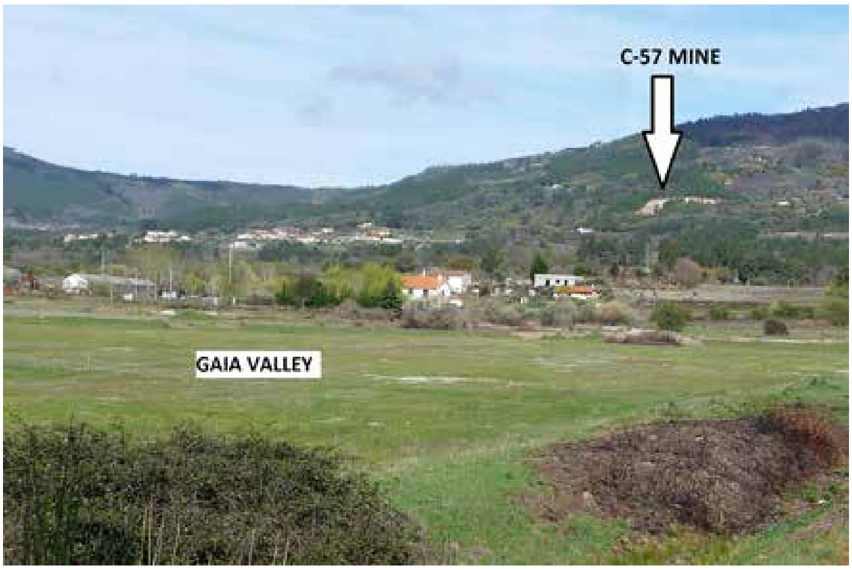

Figure 3: The Gaia valley and the C-57 mine outcrops.

cation institutions of the region (Instituto Politécnico da Guarda, Instituto Politécnico de Castelo Branco and Instituto Politécnico de Tomar) and the national professional association (Associação Portuguesa de Geólogos).

The objectives of this project are the preservation and sustainability of lithium, as well as the development of innovative proposals for tourism in the region to promote the cultural mining heritage in the Gaia valley (***Figure 3***). As this is currently the only region in Portugal with lithium ore extraction/production, the realisation of this project will create in this zone a new set of industrial and commercial activities in the so-called territories of low population density, which will certainly strengthen the zone within the central region of the country. The main priority is the evaluation of natural endogenous resources associated with territorial innovation. Other principal concerns of this project are the preservation and sustainability of this resource (lithium), by the development of product, processes and services, as well as the development of innovative proposals for encouragement of tourism in the region, aimed at the promotion of the mining heritage in the Gaia valley where the C-57 mine is operating

In recent years, tourism is one of the most important sectors of the national and international economy, and the reasons for this success vary. The World Tourism Organisation (UNWTO, 2017) predicts that global revenues from international tourism can achieve the value of 2 billion USD in 2020, which will require an average annual growth of 6 to 7% for the period 1995–2020, much higher than that estimated for the rest of the economy (3.3%), thus providing a prominent place. However, this growth is closely linked to increasing diversification and competition among tourist destinations. The contribution of tourism to the economic development of countries depends on the quality of the revenue that tourism offers. As tourism is a social and economic phenomenon, characterised by various segments of demand, it can be an element of development of the municipalities and regions that require other sources of revenue or even revitalise the local economy. Thus, we must know how to position tourist destinations in a sustainable way in the national and international markets, which are increasingly demanding and complex.

Because one of the few operating lithium feldspar mines in Portugal is located here, acting as an important source of income for the region, we can consider this zone a kind of "gathering place" for those who are passionate about the study of lithium. For this, it is necessary to integrate a considerable number of sites of geological interest which, by their peculiarities or rarity, present value or relevance in scientific, educational, cultural, economic and aesthetic endeavours, and may be considered as places to visit. These sites must have other reasons of interest and value, such as ecological, cultural, and historical theme parks or other infrastructures, which should be linked in a network, for tracks, thematic scripts and routes. Thus, it is essential that the structures associated with the mines of the region share knowledge, cultures and experiences, so that all together can position themselves successfully as a destination.

As a former mining area with visible deep scars on the territory and in the local community, the involvement of the population through knowledge of the advantages of their natural heritage of geological origin is very important. The elaboration of thematic pathways relating to mining heritages, delimitation of an "open-air museum", as well as the implementation of visits of schools on all education levels (Moreira *et al.*, 2014) and other institutions, aims at the promotion of this resource in the structuring of differentiated tourism products, such as geotourism and the tourism of experiences. Therefore, the aim is to disclose their own territory to the local community, maximising it as a specific product in the region, which has so far been somewhat ignored on a national scale and in the tourist industry.

To pursue these objectives, the proposed activities are developed in the following areas: Topography and Land Survey, Geology and Geotechnics, Environmental impact studies and Geotourism. It is the intention also of the mining partner of this project to complement its activities with the promotion of a cultural/scientific and touristic product. The tasks provided for the Topography and Land Survey group will be in operation until nearly the end of the project to allow for a more accurate mapping of the landscape, through periodic recording of the morphological changes caused by the extractive activity. Further, the land survey in the area near and adjacent to the exploitation will record the geometric and geographic identification of buildings and develop an inventory of property information, which will be created within a GIS (Geographic Information Systems) database, constituting a cadastral information system. This work will be carried out using the reference system ETRS89 TM06 of PT Portugal Continental. The use of a national reference system will make it possible to integrate the resulting topographic plants into a broader territorial context, and so make it possible to expand the level of analysis to other projects in the medium or long term. The representation and three-dimensional modelling of the mining area will make it possible to achieve a better view of the evolution of extraction of material from the vein, and to better plan and manage continuous extraction.

The tasks proposed for the geological and geotechnical activities are a surface geological survey and a geophysical prospection to identity the buried mineralised structures. The proposed environmental impact studies are intended to clarify how extractive activity interferes with the quality/quantity of water and air resources in the region. The determination of water quality upstream and downstream of the zone influenced by mining aims to evaluate potential impacts on water bodies through the analysis of physical and chemical parameters such as alkali, alkaline earth, transition and post-transition metals by atomic absorption spectroscopy with atomisation by flame and a graphite furnace. Some anions like chlorides, nitrates, sulphates and phosphates will be determined by ion chromatography techniques. Suspended solids will also be evaluated as well as the electrical conductivity and pH. For the assessment of soil quality and the environmental impact that mining can cause in the surrounding area, determination of alkali, alkali earth, transition and post-transition metals (Al, Au, Ca, Cd, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, Sn and Zn) will be carried out on representative soil samples.

The assessment of air quality will be carried out with a mobile laboratory, which will perform monitoring at different points of the surrounding mining area. The main equipment and accessories installed in the mobile lab are for the determination of PM10 particles, nitrogen oxides, ozone, carbon monoxide, sulphur dioxide, a VOC-BTX analyser for the determination of benzene, toluene, ethylbenzene, m+p-xylene, o-xylene, and a hydrocarbon analyser. As a result of the monitoring activities, reports will be prepared of the impacts of this activity on the quality of water, air and soil. The intention of this study is to inform local inhabitants about these resources to counteract the absence of data that often translates into an ignorance that can be very harmful in terms of public health. These activities will be carried out by teachers and students of Topographic and Environment courses. In this way student learning can be enhanced through the Problem Based Learning approach, enriching the academic experience and enabling students to develop skills in a real environmental context.

The Geotourism group will prepare routes/thematic itineraries and design an open-air museum. The image of the touristic destinations depends on what they offer. It is essential that there is an innovative offer which responds to the motivations and expectations of visitors and tourists. In this way, the thematic routes emerge as one of the possible answers, to the extent that they demonstrate their ability to attract visitors/tourists, contributing to the increased visibility of the local tangible and intangible heritage and to the improvement of the image of the destination. The development of products, processes and services with a view to boosting value chains associated with natural geological resources and with the local traditions and customs will be one of the aspects to be explored in this activity. The development of innovative proposals for tourism in the region needs the cooperation of the local population, who will see in this activity a way to highlight the geological singularity of the region associated with a tertiary sector activity that will undoubtedly bring a projection of the region into the panorama of national sustainable tourism. The routes will be geo-referenced and will be expressed in a digital platform (web page) of the project. This digital platform will be also transformed into a mobile application, allowing visitors access to multiple types of information associated to the geomining routes to be established. The following thematic routes are proposed: Route 1 – linked to previous mining activity of the Vale da Gaia. The geological and mining pathways should be implemented in logic of understanding the geological history of the place, as well as their contextualisation in the evolution of the Earth, adding cultural value and scientific, socio-economic and educational importance to the region; Route 2 – a religious path connected with Saint Barbara, patron of miners; Route 3- a cultural route connected to the basketry typical of Gonçalo village.

The Open-Air Museum would be located on the former C-57 mine installations, which would allow an open window to the knowledge of the origin of the pegmatites on Earth and a historical stone witness and unique assets in the country related to the ancient mining of lithium. The thematic routes should be designed to converge in the museum space, which would be the centre of all activities to be performed. The entire museum and the thematic routes will be a socio-economic added value for the region, acting as a possible structure of innovative tourism products. This action in cooperation with the owner of the C-57 mine, aims to contribute to the cultural enrichment and tourism promotion of the locality of Gonçalo and to raise awareness of young students to the natural sciences and to the exploitation of natural resources. These objectives will be maximised by the local population's involvement in the preparation of the activities, through the collection of their experience and diverse materials that reflect the mining activities of the past.

The development of the Open-Air Museum, complemented by the proposal for the elaboration of thematic pathways in the aforementioned network, will reduce problems of seasonality, encourage job creation and promote public awareness for the preservation of the cultural and environmental heritage, bringing in general an undeniable asset and promoting the sustainability of this region.

It is hoped in the future to create a joint venture between mining companies and cultural tourism through the development of thematic routes promoting the beauty of natural resources, especially those of geological type, which could be attractive not only to the local inhabitants but to a much wider population. The recent approval by the Portuguese government of a National Strategy for Nature Conservation and Biodiversity for 2030 (Resolution of the Council of Ministers No. 55/2018, 7 May 2018) undoubtedly points to the path of conservation of the values of the natural heritage and its geodiversity with the safeguard of the cultural identity.

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The application of European hazardous waste assessment to mining projects and implications for environmental sustainability

Melanie Cox, Robert Bowell, Carl Williams, Julien Declercq, Jessica Charles, Ruth Warrender and Craig Wickham*

European mine waste management is governed by the Extractive Waste Directive (2006/21/EC) but hazardous assessments are conducted according to a broader hazardous classification legislation encompassing all waste types. Consequently, there is a risk of misinterpretation when using one system for all wastes.
This article assesses potential issues with the current approach. Literal interpretation of the legislation could over-emphasise or under-estimate risks and hazardous classification focuses on solid phase compositions, with minimal consideration to leachate formation over time.
Correct designation of waste is essential; it influences waste management plans and has implications for categorisation of mining waste facilities. Tailoring each site-specific assessment is crucial and a variety of information sources and legislative documents should be consulted to provide the most relevant classification.

La gestion des déchets miniers européens dépend de la Directive sur les Déchets Miniers (2006/21/EC) mais des évaluations aléatoires sont réalisées selon une législation qui porte sur une classification très fantaisiste concernant l'ensemble des types de déchets. En conséquence, un risque d'interprétation erronée existe quand on utilise un seul système, quel que soit le déchet.
Cet article évalue les résultats potentiels avec une approche actuelle. Une interprétation littérale des directives pourrait surévaluer ou sous-estimer les risques tandis qu'une classification aléatoire met l'accent sur les éléments en phase solide, avec un minimum de considération pour la formation de lixiviats, avec le temps.
Une dénomination correcte des déchets est essentielle; elle conditionne les plans de gestion de déchets et conserve une implication dans la catégorisation des installations de déchets miniers. Effectuer une évaluation spécifique propre à chaque site est crucial et les sources d'information variées associées aux documents législatifs ad hoc devraient être consultés pour établir la classification la plus pertinente.

Los residuos mineros de Europa están regulados por la Directiva de residuos de las industrias extractivas (2006/21/EC) sin embargo, las evaluaciones de peligrosidad se llevan a cabo de acuerdo a una legislación de clasificación de riesgos más extensa que incluye todos los tipos de residuos.
Este artículo asesora sobre problemas potenciales que presenta el enfoque actual. La interpretación literal de la legislación podría hacer demasiado hincapié o subestimar riesgos, y la clasificación de riesgos se centra en composiciones en fase sólida, considerando mínimamente la formación de lixiviados a lo largo del tiempo.
La denominación correcta de residuo es esencial: determina los planes de gestión de residuos y tiene implicaciones para la clasificación de las instalaciones de residuos mineros. Adaptar la evaluación a cada lugar es crucial y se deberían consultar diferentes fuentes de información y documentos legislativos para obtener la clasificación más relevante.

Introduction & Background to European Legislation Governing Hazardous Waste

This article considers the current European legislation governing the classification of hazardous waste in the context of mining waste, highlighting the possible issues that may be faced and how this has the potential to affect environmental sustainability. Within Europe, assessment of mine waste is governed by the Extractive Waste Directive (EWD) (2006/21/EC). The EWD enables the characterisation of waste as inert or non-inert depending upon sulphide content and metal concentrations; however, the classification of hazardous waste is governed by a broader legislative scope which encompasses all waste types including domestic and industrial sources. Classification of mine waste should involve a holistic approach that considers all aspects of legislation collectively, together with a thorough geochemical assessment and predictive modelling; applying the hazardous classification alone could potentially result in risks being under-estimated or issues over-emphasised.

A number of waste legislation documents exist, including key documents summarised in ***Figure 1***. Documentation can be frequently amended or updated, so experience in applying the most relevant is essential. In the mining industry, the classification impacts the mine waste management plan and has implications for the categorisation of waste facilities. Where waste is classified as hazardous it must be stored in a 'Category A' facility, which has administrative, economic and social implications on the mine in terms of monitoring, construction, regulatory scrutiny, financial security and public perception.

A report assessing the performance of Member States regarding the implementation of the EWD (EC, 2017) concluded that there were inconsistencies regarding the application of the criteria for classification of waste facilities as Category A, suggesting that the legislation is subjective and open to interpretation. A recent technical guidance has been published (EC, 2018) to assist with waste classifications and although this provides a useful tool, it is not tailored specifically towards the mining industry, so experience in interpreting and applying all of the legislation together is essential.

Waste assessments should be tailored to each site from an early stage in order to establish an adequate sampling program.

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A variety of information sources should be consulted as part of the assessment in order to provide the most appropriate categorisation; these include current legislation, chemical databases and site-specific data.

To maintain environmental sustainability the EWD encourages recycling, reclaiming and reusing of waste rock and tailings materials. A separate geochemical and geophysical assessment is required to assess rock suitability for uses such as construction materials for waste facilities or roads. The hazardous waste classification is not sufficient to assess environmental impacts and a more thorough risk assessment approach should be used. Ideally, the assessment of the suitability of waste rock for reuse should be made before the materials are officially classified as "waste" and enter the waste stream.

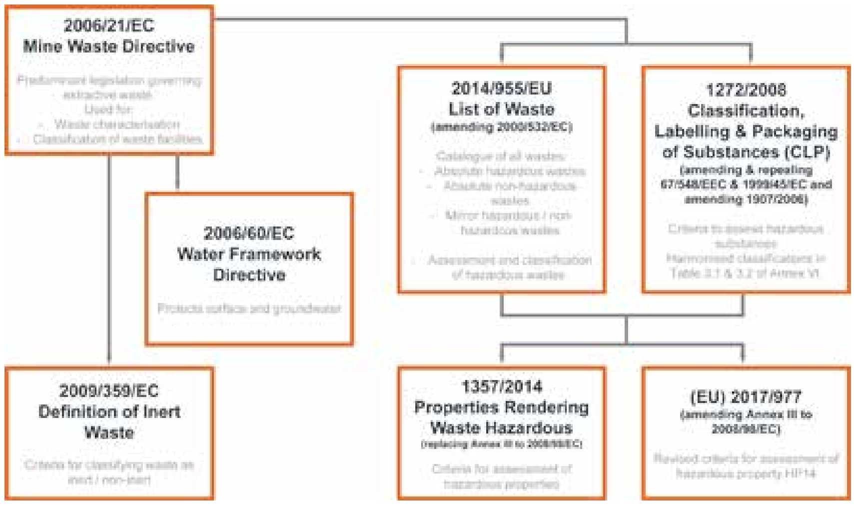

Figure 1: Summary of the current key legislation pertaining to hazardous waste assessments.

Potential Challenges of Applying the Hazardous Waste Assessment to Mining and Implications for Environmental Sustainability

List of Wastes

The List of Waste (LoW) (2014/955/EU) is a catalogue of waste codes assigned to any type of waste. All LoW entries fall under one of the following categories:

- Absolute hazardous (automatically hazardous regardless of any classification),
- Absolute non-hazardous (automatically non-hazardous),
- Mirror hazardous or mirror non-hazardous (potentially hazardous or not depending upon the classification outcome).

A significant amount of mine waste rock can be classified as:

- 01.01.01 wastes from mineral metalliferous excavation
- 01.01.02 wastes from mineral non-metalliferous excavation

Both of these European waste codes are "absolute non-hazardous" entries which, in theory, require no further hazardous assessment. In the case of mining waste, allocation of one of these codes has the potential to have significant negative impacts on the environment, since waste rock can have acid generating and metal leaching potential. Whilst the Waste Framework Directive (WFD) specifies that waste can be considered hazardous if it displays hazardous properties, even if it does not appear as such on the LoW, officially extractive waste is excluded from the WFD scope.

The requirements of the EWD are to ensure that waste is managed to prevent harm to the environment (including water, air, soil, flora and fauna) and prevent any negative impact to human health. In which case, relying solely on an absolute non-hazardous code is inappropriate and a more in-depth geochemical and geophysical assessment is necessary.

Sampling and Analysis

For the majority of industries, the waste classification process is carried out on an actual waste product generated. However, in the case of the mining industry, the hazardous assessment often needs to take place at the planning stage before any waste is produced. Guidance on material sampling and testwork is given in Council Regulation 440/2008 and European and British Standard (BS EN 14899:2005) plus supporting Technical Reports. Since all mine sites are different, it is important to develop a site-specific sampling program which is tailored to include an appropriate suite of analytes, number of representative samples and suitable limits of detection, low enough to assess any potential environmental impacts and compare to natural baseline levels.

An unsuitable sampling plan can lead to potentially significant environmental impacts if, for example, key parameters are not included in the hazardous assessment or if the selected samples are not entirely representative of the likely future waste. Care should also be taken to address material heterogeneity. Hazardous assessments often focus solely on multi-element assay data but consideration must also be given to leachate generation under the broader extractive waste legislative scope. Mineralogy data should be considered, but can raise issues through potential false flags, discussed further below. It may be necessary to consider particle size distribution (PSD) to determine grain sizes and whether substances are present in respirable form, or more specialist testwork such as flammability or slake durability testing. Processing chemicals must also be considered in tailings waste.

The hazardous assessment process can be undertaken on any number of parameters and there are no specifications for minimal detection limits, therefore a high level of technical knowledge is crucial to ensure that the assessment is robust enough to meet regulator/stakeholder requirements.

Leachate Generation from Mining Waste

Hazardous waste assessment legislation typically focuses on solid phase composition, with minimal attention to leachate formation. Generally, solid waste is assessed according to hazard properties HP1 to HP15 and any leachates are assessed as separate waste streams. The hazardous assessment informs the classification of mine waste facilities (MWF) and, according to the EWD, a MWF must be designed to prevent pollution to surface and groundwater. Therefore, a more environmentally sustainable approach would be to consider leachate generation in conjunction with the hazardous waste assessment on solids.

Hazardous assessment legislation makes

limited reference to leachates but there are no clear guidance or assessment criteria:

"....... Member States may characterise a waste as hazardous by HP15 based on other applicable criteria, such as an assessment of the leachate." (1357/2014)

Whilst risks to water bodies are considered under separate legislation including the Water Framework Directive (2000/60/EC), there does not appear to be a clear overlap with the hazardous assessment process. This could lead to a non-hazardous classification for wastes capable of leaching metals to the environment. Commission Decision 2009/337/EC also states that facilities containing reactive waste must be assessed to evaluate the release of contaminants which may result from incorrect operation of the facility during operations and post-closure regardless of whether materials are hazardous or non-hazardous. This supports the hypothesis that a full geochemical and geophysical assessment is necessary for any material stored in a waste facility; a hazardous assessment alone is not sufficient and an integrated approach is required.

Table 1 gives an example of geochemical testwork results for a greywacke sample taken from a potential mine site in Europe. The sulfide concentration is 4.09% and antimony, arsenic, cadmium, lead, tin and zinc are elevated by more than three times the average crustal abundance. Short-term

Table 1: Example of key assay data for greywacke sample.

Parameter	Test Method	Units	Greywacke	Average Crustal Abundance (Mason, 1966)	Environmental Quality Standards (2008/105/EC & 2013/39/EU)
Total Sulphur	EN 15875	%	4.46	--	--
Sulfide Sulphur	EN 15875	%	4.09	--	--
Paste pH		s.u.	4.84	--	--
Acid Generating Potential (AP)	EN 15875	kg $CaCO_3$/t	128	--	--
Neutralising Potential (NP)	EN 15875	kg $CaCO_3$/t	<0.25	--	--
Antimony	4 Acid Digest & ICP	mg/kg	35.9	0.2	--
Arsenic	4 Acid Digest & ICP	mg/kg	80.1	1.8	--
Cadmium	4 Acid Digest & ICP	mg/kg	24.7	0.2	--
Cobalt	4 Acid Digest & ICP	mg/kg	12.1	25	--
Copper	4 Acid Digest & ICP	mg/kg	199	904	--
Lead	4 Acid Digest & ICP	mg/kg	62.1	13	--
Manganese	4 Acid Digest & ICP	mg/kg	567	950	--
Molybdenum	4 Acid Digest & ICP	mg/kg	<5	1.5	--
Nickel	4 Acid Digest & ICP	mg/kg	50.3	75	--
Tin	4 Acid Digest & ICP	mg/kg	350	2	--
Zinc	4 Acid Digest & ICP	mg/kg	1137	70	--
Leachate pH	EN 12457-4	s.u.	2.17	--	--
Antimony, Leached	EN 12457-4	µg/L	0.5	--	--
Arsenic, Leached	EN 12457-4	µg/L	<2.50	--	--
Cadmium, Leached	EN 12457-4	µg/L	5.59	--	0.9 (*) MAC
Cobalt, Leached	EN 12457-4	µg/L	71.5	--	
Copper, Leached	EN 12457-4	µg/L	60.4	--	
Lead, Leached	EN 12457-4	µg/L	4.6	--	14 MAC
Manganese, Leached	EN 12457-4	µg/L	4930	--	
Molybdenum Leached	EN 12457-4	µg/L	<0.50	--	
Nickel, Leached	EN 12457-4	µg/L	63.4	--	34 MAC
Tin, Leached	EN 12457-4	µg/L	<10.0	--	
Zinc, Leached	EN 12457-4	µg/L	6780	--	

Notes:

Indicates concentrations elevated by more than three times the average crustal abundance

Indicates leachate concentrations exceeding EU Environmental Quality Standards

MAC = maximum allowable concentration

AA = annual average concentration

Where both a MAC and AA guideline exist the more lenient MAC has been used

(*) MAC for Cd (0.9 µg/L) based upon Class 4 hardness (100 to <200 mg/L of $CaCO_3$). Hardness in Greywacke calculated at 137 mg/L.

leach test results showed that cadmium and nickel were leached at concentrations exceeding the European Environmental Quality Standards (2013/39/EU). However, ***Figure 2*** illustrates that the solid sample is classified as non-hazardous according to hazardous waste legislation, which includes an assessment of ecotoxicity (HP14).

Hazardous Waste Classification of Leachates

Chapter 19 of the LoW refers to: *wastes from waste management facilities, off-site waste water treatment plants and the preparation of water intended for human consumption and water for industrial use*. In theory, leachates could be given a European Waste Code from this chapter and assessed using the same methodology as is applied to solids. In this instance, the leachates are considered as a separate waste stream so this does not address the issue of whether solid waste should be classified as hazardous in the first instance based on its potential to generate a harmful leachate.

The hazardous waste legislation does not specify separate threshold values for leachates, and employing a simple conversion to the solid thresholds is inappropriate for assessing environmental impacts. For example, the lowest ecotoxic threshold for mercury which will trigger a hazardous classification by HP14 is currently 0.25% (equivalent to 2500 mg/kg or 2500 mg/L, with minor adjustments due to density effects). This is significantly higher than the MAC of 0.07 µg/L (2013/39/EU) (***Table 2***).

New legislation governing the classification of HP14 Ecotoxic comes into force in July 2018 but this will generally result in identical or more lenient thresholds.

Over-Estimating Hazardous Risks

Over-estimating hazardous properties could initially be viewed as the most conservative approach, with more waste facilities being classified as Category A. However, considering the triple bottom line (social, environmental and financial), it is not necessarily the best approach. For example, the emplacement of Category A facilities can have huge social implications such as the NIMBY ("Not In My Back Yard") concept. There are obvious additional financial and administrative commitments for any mine constructing a Category A facility. There is also a potential for environmental regulatory focus to be diluted if everything is classified as Category A rather than the cases where it really is necessary for hazardous

Non Hazardous Waste
Classified as **01 01 01**
in the List of Waste

Hazard properties

None identified

Determinands

Moisture content: 0% No Moisture Correction applied (MC)

#	Determinand	CLP index number	EC Number	CAS Number	CLP Note	User entered data		Conv Factor	Compound conc.		Classification value	MC Applied	Conc. Not Used
1	antimony { antimony trioxide }	051-005-00-X	215-175-0	1309-64-4		35.9	mg/kg	1.197	42.976	mg/kg	0.0043 %		
2	arsenic { arsenic compounds, with the exception of those specified elsewhere in this Annex }	033-002-00-5			1	80.1	mg/kg		80.1	mg/kg	0.00801 %		
3	beryllium { beryllium }	004-001-00-7	231-150-7	7440-41-7		<5	mg/kg		<5	mg/kg	<0.0005 %		<LOD
4	cadmium { cadmium oxide }	048-002-00-0	231-152-8 [1] 215-146-2 [2]	7440-43-9 [1] 1306-19-0 [2]		24.7	mg/kg	1.142	28.216	mg/kg	0.00282 %		
5	chromium in chromium(III) compounds { chromium(III) oxide }		215-160-9	1308-38-9		61.3	mg/kg	1.462	89.593	mg/kg	0.00896 %		
6	chromium in chromium(VI) compounds { chromium (VI) compounds, with the exception of barium chromate and of compounds specified elsewhere in this Annex }	024-017-00-8				61.3	mg/kg	1.923	117.885	mg/kg	0.0118 %		
7	copper { copper(II) carbonate – copper(II) hydroxide (1:1) }	029-020-00-8	235-113-6	12069-69-1		199	mg/kg	1.74	346.219	mg/kg	0.0346 %		
8	lead { lead compounds with the exception of those specified elsewhere in this Annex }	082-001-00-6			1	62.1	mg/kg		62.1	mg/kg	0.00621 %		
9	manganese { manganese dioxide }	025-001-00-3	215-202-6	1313-13-9		567	mg/kg	1.582	897.251	mg/kg	0.0897 %		
10	mercury { mercury }	080-001-00-0	231-106-7	7439-97-6		<0.38	mg/kg		<0.38	mg/kg	<0.000038 %		<LOD
11	molybdenum { molybdenum(VI) oxide }	042-001-00-9	215-204-7	1313-27-5		<5	mg/kg	1.5	<7.501	mg/kg	<0.00075 %		<LOD
12	nickel { nickel sulfide }	028-006-00-9	240-841-2 [1] 234-349-7 [2] - [3]	16812-54-7 [1] 11113-75-0 [2] 1314-04-1 [3]		50.3	mg/kg	1.546	77.78	mg/kg	0.00778 %		
13	selenium { selenium compounds with the exception of cadmium sulphoselenide and those specified elsewhere in this Annex }	034-002-00-8				<0.5	mg/kg	2.554	<1.277	mg/kg	<0.000128 %		<LOD
14	zinc { zinc oxide }	030-013-00-7	215-222-5	1314-13-2		1137	mg/kg	1.245	1415.24	mg/kg	0.142 %		
										Total:	0.317 %		

Key

User supplied data

Determinand values ignored for classification, see column 'Conc. Not Used' for reason

Speciated Determinand - Unless the Determinand is Note 1, the Conversion Factor is used to calculate the compound concentration

<LOD Below limit of detection

CLP: Note 1 Only the metal concentration has been used for classification

Figure 2: Example of non-hazardous classification.

waste. Inexperience in applying the hazardous waste legislation to mine waste can lead to over-estimation of hazards.

Worst-Case Compounds

In many industries waste chemical compounds may be well known; however, in the case of mine waste it may not be possible to analyse for all specific substances likely to exist, particularly if the mine is still in the planning stage. 2018/C 124/01 guidance advises on a 'reasonable worst case' approach to selected substances. Simply opting for an absolute worst-case every time can result in a potential over-estimation of hazardous properties and inappropriate waste classification. A multi-element assay provides concentrations of individual elements so it is necessary to apply a good level of understanding of the chemical and physical properties of various compounds likely to be present under the conditions anticipated within the waste, considering factors such as solubility or reactivity plus site-specific geology.

Mineralogical Data

Mineralogical data can be included in the hazardous waste assessment process. However, a strong understanding is essential to

Table 2: Example of hazardous assessment thresholds for mercury.

Parameter	Mercury
CAS Number	7439-97-6
MAC EQS 2013/39/EU	0.07 µg/L

Hazard Class & Category Code	Hazard Statement Code	Hazard Properties	Solid Threshold (%)	Equivalent Threshold (mg/L)*
STOT RE 1	H372	HP5	1.0	10018
Acute Tox. 2	H330	HP6	0.5	5009
Repr. 1B	H360D	HP10	0.3	3005
Aquatic Acute 1 & Aquatic Chronic 1	H400 & H410	HP14	0.25	2504

* Includes density conversion factor of 0.99821 g/cm^3

ensure that results are applied correctly, as it is possible to misinterpret the legislation or guidance, which can lead to an unnecessary hazardous classification. Some of the most abundant minerals within Earth's crust are listed in the C&L Inventory (ECHA) with numerous hazardous properties associated with them. ***Table 3*** provides some examples for quartz, feldspars and muscovite, including threshold values at which they would be classified as hazardous.

These minerals may be present in large quantities within mine waste, regularly exceeding the maximum 25% threshold. The average crustal abundance of silica is 27.7% (Mason, 1966), and a literal interpretation of the guidance could therefore result in a hazardous classification for what may otherwise be inert waste rock. In this instance, it is important to consider the physical form of substances. All of the hazard statement codes listed in ***Table 3*** relate to ingestion, eye irritation or respiratory inhalation and are therefore related to the substances in a dust form rather than at the coarser grain sizes likely to occur in nature; the hazards for quartz for example, would relate to silica dust. Therefore, it would be inappropriate to classify all waste rock as hazardous based upon a high quartz content. There is an opportunity to support this with particle size distribution data for the waste in question, if necessary.

It is also important to note that these mineralogical entries in the CLP are non-harmonised; they have not been formally classified at EU level. To fully assess the risks, a variety of peer reviewed scientific data sources should be considered including, but not limited to, the Registered Substances Database, IARC Monographs and peer reviewed scientific papers, to present a comprehensive case for any hazardous/non-hazardous classification.

Summary

European legislation relating to the classification of hazardous waste is generic to a variety of industries and not tailored specifically to mining. To ensure the protection of the environment and appropriate classifications, assessments conducted on mining waste need to use a more holistic approach encompassing several pieces of key legislation relating to hazardous waste classification, the EWD and Water Framework Directive. Experience in understanding and applying the various legislative sources is necessary for environmental protection. It can also affect the financial and administrative commitments of the mine and have significant social implications.

The initial aim should be to reuse, reclaim or recycle waste even before it enters the waste stream. In the case of mining, this could include using waste rock in construction. A thorough geochemical and geophysical assessment is required in this instance to ensure suitability for use; it is not appropriate to rely solely on a hazardous assessment.

A number of challenges may be faced when applying the European hazardous waste classification to mining waste if other legislation is not taken into consideration as part of the process. According to the List of Waste (2014/955/EU) there is an opportunity to automatically categorise waste rock as an absolute non-hazard but it is essential that the materials are assessed for their potential to generate acid or leach metals that could have a detrimental effect on the environment. The assessment should be in accordance with the EWD and other industry-recognised guidance such as the Global Acid Rock Drainage (GARD) Guide (INAP, 2017).

Without relevant experience, it is possible to conduct an inadequate testing program, potentially missing key parameters or using unsuitably high detection limits. Minimum requirements are not flagged as part of the waste assessment and therefore a high level of technical knowledge is essential.

The hazardous assessment process places a great deal of emphasis on concentrations of hazardous properties within solid waste and there is minimal focus on the potential for that waste to generate leachates that may have a negative impact on surface or groundwaters. Solely following a hazardous classification approach, it is possible to categorise potentially acid generating waste with elevated metals content, as a non-

Table 3: Example hazard statement codes associated with common earth minerals.

Mineral	CAS-Number	Hazard Statement Codes	Threshold (%)	Harmonised / Non-harmonised
Quartz (SiO_2)	14808-60-7	H302	25%	Non-harmonised
		H319	20%	
		H332	22.50%	
		H335	20%	
		H341	1%	
		H350	0.10%	
		H351	1%	
		H372	1%	
		H373	10%	
Feldspar Group Minerals	37244-96-5, 68476-25-5	H319	20%	Non-harmonised
		H335	20%	
		H372	1%	
		H373	10%	
Muscovite	1318-94-1	H319	20%	Non-harmonised

hazardous waste. It is therefore essential to adhere to other legislation such as the EWD alongside any hazardous classification. If leachates are assessed according to the same thresholds as solid waste, the limits offer no protection to the environment.

There are several ways in which hazardous risks may be over-emphasised if the waste classification is not appropriately applied. For example, not selecting an appropriate species within the waste can result in an over-estimation if a worst-case scenario approach is adopted. Common minerals within rock (for example quartz) can trigger an unnecessary hazardous classification if a literal approach is applied.

In summary, the EU hazardous waste assessment process should not be applied to mining waste in isolation. Whilst it can help inform decisions regarding the categorisation of waste storage facilities, the hazardous assessment legislation alone may not provide complete environmental protection. Mine waste classification requires an integrated approach where all aspects of the legislation are addressed in unison.

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Radically decreasing the emissions of fossil and renewable energy materials and waste landfills

*Dr. Robert I. Hargitai**

The need for a clean energy is a global issue. In the European countries there is a huge amount of solid/gaseous/liquid fossil fuel consumption, which mostly comes from imports. CO2 emissions from the use of these conventional fuels continue to add thousands of tons of greenhouse gases each year to the atmosphere, as a significant contributor to global warming. Not to mention that the cost of these fuels continues to rise with the uncertainty of supply. There is another problem in the EU and worldwide: how to manage and eliminate the huge quantity of organic waste materials. Neither incineration nor landfilling is an acceptable solution due to the enormous quantity of harmful emissions of these processes. Both fossil energy source materials and organic wastes can be used in "green energy" production with the application of a tested and proven "clean coal" technology, TCG – Thermo-Chemical Gasification – developed in the US.

Le besoin d'énergie propre constitue un problème global. Dans les pays européens, la consommation de carburant d'origine fossile, solide, gazeux ou liquide, dont la plus grande partie est importée, représente un chiffre énorme. Les émissions de CO2 produites par l'utilisation de ces carburants conventionnels, chaque année, rajoutent à l'atmosphère des milliers de tonnes de gaz à effet de serre, et contribuent de façon significative au réchauffement climatique. Cela sans mentionner l'augmentation progressive de ces carburants, compte tenu de l'incertitude affectant les approvisionnements. Un autre problème existe au niveau européen et mondial : comment gérer et éliminer l'énorme quantité de déchets sous forme de matières organiques? Ni leur incinération ni leur mise en décharge ne représentent une solution acceptable en raison de la quantité phénoménale d'émissions dangereuses émises lors de ces procédés. Aussi bien les matières fossiles, sources d'énergie que les déchets organiques peuvent être utilisés sous forme de produits d'"énergie verte" après utilisation d'une technologie, développée aux Etats-Unis, testée et prouvée, celle du "charbon propre", TCG ou - Gasification Thermo-chimique.

La necesidad de energía renovable es un asunto global. En los países europeos se consume una cantidad inmensa de combustibles fósiles en estado sólido, gaseoso y líquido, la mayoría se importa. Las emisiones de CO2 debido al uso de estos combustibles tradicionales incrementa en miles las toneladas de gases de efecto invernadero cada año en la atmosfera, y contribuye al calentamiento global. Por no mencionar que el coste de estos combustibles continúa incrementado debido a la incertidumbre del suministro. Además, hay otro problema en la Unión Europea y a nivel internacional: cómo gestionar y eliminar la gran cantidad de residuos orgánicos. Ni la incineración ni el vertido es una solución aceptable debido a la enorme cantidad de emisiones dañinas de estos procesos. Tanto las fuentes de energía fósiles como los residuos orgánicos se pueden usar para la producción de energía renovable con la aplicación de la tecnología probada y testada denominada TCG (Thermo-Chemical Gasification: Gasificación Termo Química) desarrollada en los Estados Unidos.

Introduction

Here is the opportunity for both the revitalization of the coal mining industry and the environmentally clean industrial application of fossil energy sources or organic wastes, thanks to the near-zero emissions of a proven clean coal technology. This is a major step forward in tackling the emissions problems connected with energy generation and with disposal of organic waste.

The fossil energy sources of Europe and the danger of emissions

Although there is a huge quantity of fossil energy source materials in Europe, we do not mine and use them; instead, we are importing these materials to meet the energy needs, and are making huge efforts to increase the ratio of green energy in the total energy consumption of Europe.

Politicians and most experts think that coal and other fossil fuels are the main risks to the environment, and cause the biggest part of the greenhouse gas (GHG) emissions. Thus, the European Union launched certain measures against fossil fuels, mostly against coal mines and coal-fired power plants. During the last 15 years some important steps have been taken on this route. The governments of the EU Member States (MS) step-by-step decreased – and later withdrew – subsidies supporting the home mining industry against the cheap coals of the world market (in Regulation (EC) No. 1407/2002) and Council Decision of 10 December 2010 on State aid to facilitate the closure of uncompetitive coal mines (2010/787/EU)). Later on, the not "economically operated" mines were closed, and the CO2 quota system was introduced.

According to industry experts, unless coal emissions are phased out within the next 15 years, we will not meet the targets for carbon reduction as promised in the Paris Agreement. Although coal output is falling by approximately 1% per year overall, it still accounts for a quarter of all energy produced in Europe, and a fifth of its greenhouse gas emissions. Referring to the Paris agreement, which has been signed by 26 European states, the UK announced that all coal-fired plants will be completely replaced by 100% carbon-neutral sources by the year 2050. Moreover, it is all the same if we use European or Australian coal – harmful gases and elements are continuously emitted, because the technology is not a "zero emission" one.

Another major question is grid expan-

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Table 1: Life cycle CO_2 equivalent (including albedo effect) from selected electricity supply technologies (gCO2eq/kWh).

Technology	Min.	Median	Max.
Coal – PC	740	820	910
Biomass – Co-firing with coal	620	740	890
Gas – combined cycle	410	490	650
Biomass – Dedicated	130	230	420
Solar PV – Utility scale	18	48	180
Solar PV – rooftop	26	41	60
Geothermal	6.0	38	79
Concentrated solar power	8.8	27	63
Hydropower	1.0	24	2200
Wind Offshore	8.0	12	35
Nuclear	3.7	12	110
Wind Onshore	7.0	11	56
Commercial, proven, TCG Technology (independently from feed material)	**cca. 0**	**cca. 0**	**cca. 0**
Pre-commercial Technologies			
CCS – Coal – PC	190	220	250
CCS – Coal – IGCC	170	200	230
CCS – Gas – combined cycle	94	170	340
CCS – Coal – oxyfuel	100	160	200
Ocean (Tidal and wave)	5.6	17	28

__CCS__ – Carbon Capture and Storage
__PC__ – Pulverized Coal-fired boiler
__IGCC__ – Integrated Gasification Combined Cycle
Source: IPCC, 2014

sion, which is expensive and far behind schedule. Due to the EEG subsidy for renewable power and the decline in coal and CO2-certificate prices, wholesale electricity prices have fallen to very low levels and while coal is still needed to guarantee the security of supply, more and more coal-fired power plants can no longer operate profitably. For this supply security reason, a minimum of 10-25% of the total electricity consumption has to be generated by coal-fired power plants or other schedulable, controllable and adjustable technologies. The energy consumption and the electricity demands of developed and developing regions of the world create an almost insurmountable problem, particularly if GHG emissions must be decreased radically.

Other issues such as the limited availability of the usable land in the EU also mean a problem in the exclusive application of wind and solar energy generation. Although the efficiency of solar panels has continuously grown during the last decade, a large amount of land area is needed for the solar panels. A 500 TPD (ton/day) capacity TCG–UC W2GE power plant produces 23.78 MWh, that is, 178,107 MWh of electric energy production yearly. This power plant needs only about 2-4 ha (20,000-40,000m^2) area, while a solar power plant built with medium category Solar Power Rocks solar panels of a similar capacity would need an area of approximately 100 ha area (178,107 MWh/(1.1 MWh/6.1698 m^2) = 998,986 m^2).

According to the calculation of experts, a large part of greenhouse gases originate from combustion, which includes the effects of fossil fuels, waste incinerators, cement factories, internal combustion engines, etc. As shown in ***Table 1***, the highest emissions are produced by coal and by combined coal and biomass (co-firing with coal). Although not listed in the table, the waste incineration system also produces a large quantity of extremely harmful gas emissions.

The electricity sector has a key role to play in meeting goals for reducing GHG emissions. In the UK, the average emissions from electricity generation fell from 718 gCO_2eq/kWh in 1990 to 500 gCO_2eq/kWh in 2008. The Committee on Climate Change (CCC) recommends a further reduction to just 50 gCO_2eq/kWh by 2030 to support achievement of the national aims. This is an ambitious plan to decrease CO_2 emission if we take into consideration that the rate of emission decrease must reach 296% and the "yearly decrease" must be 242%.

Organic wastes

In a lot of countries it is vital to establish a complex plant to eliminate or at least to reduce the problems caused by the management and disposal of industrial, agricultural and Municipal Solid Waste (MSW). Landfill is unacceptable because, aside from the large area needed, it produces gases that have an influence on climate change. The major components are CO_2 and methane, both of which are greenhouse gases. In terms of global warming potential, methane is over 25 times more detrimental to the atmosphere than CO_2 (Monteleone, 2018; EPA website) and, for example, landfills are the third largest source of methane in California (SoCalGas website).

These waste materials contain large amounts of organic parts that can be used as a sustainable resource for energy generation – but only if the technology has zero emissions. Otherwise, the high emissions of incineration will accelerate global warming, while the filtering of the flue gas of incinerators will sharply increase the operating costs. A better solution has been found: Thermo-Chemical Gasification, the TCG technology.

The TGC technology

A small group of experts and scientists led by M. Wiley developed the Thermo-Chemical Gasification (TCG) technology, which has been patented worldwide[1]. It can utilize any organic material, like waste materials, or fossil fuels – such as coal, oil refinery residuals, and others – as feedstock. Moreover, it is able to use the flue gas of traditional, high-emission, coal-fired power plants as an additional feed material and build its recombined elements into the "Syngas" produced.

The TCG-UC power plant – based on TCG technology and further developments of the author and his team – provides solutions to the following important issues:

1. Fossil fuels can be used again in the electricity manufacturing, due to the near zero emission of the TCG technology,

1 (WO2007121268) METHODS AND APPARATUS FOR SOLID CARBONACEOUS MATERIALS SYNTHESIS GAS GENERATION, https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2007121268

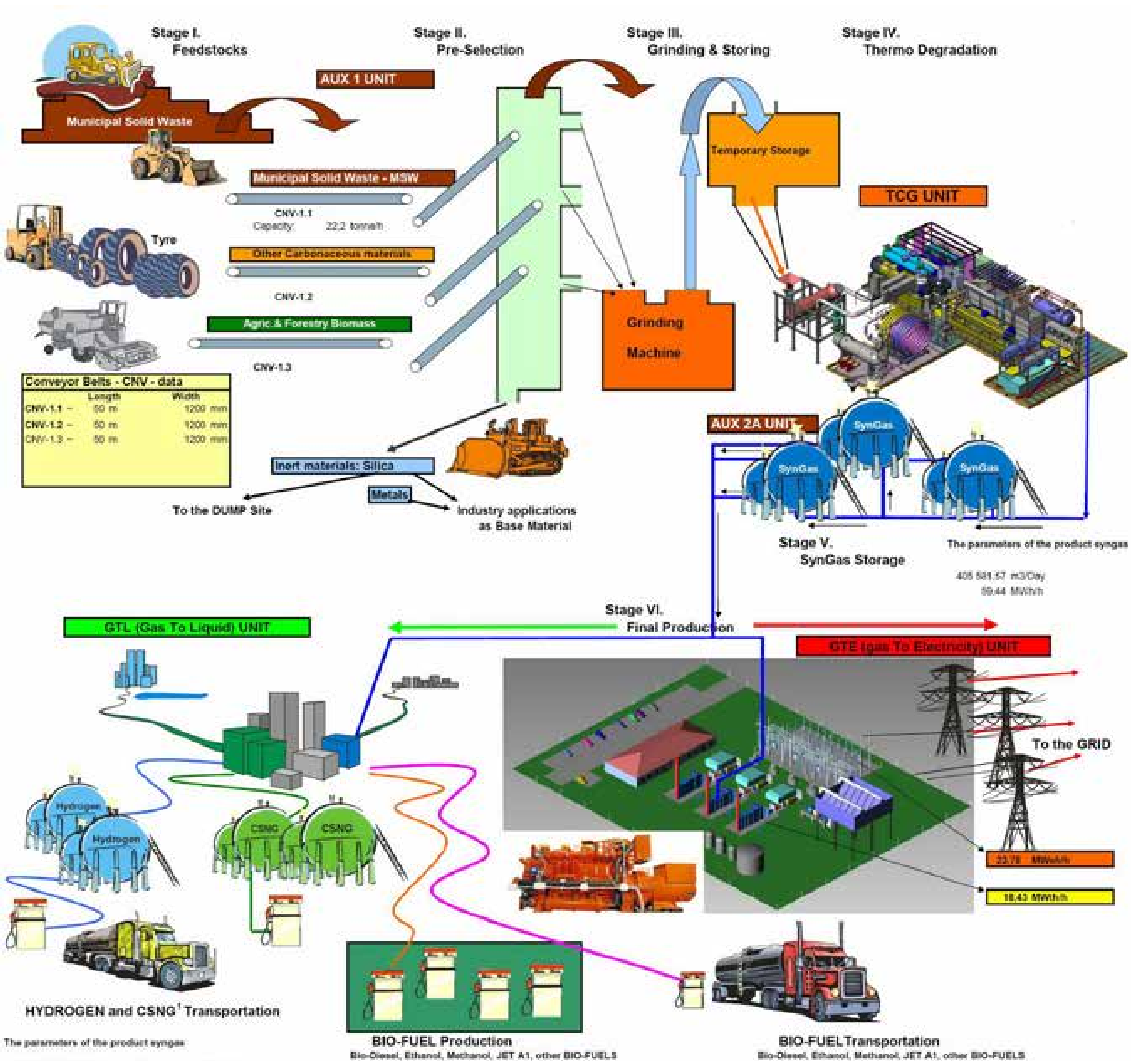

Figure 1: Process diagram of TGC-UC EL 500 plant.

2. Through using the flue gases of the traditional, coal/oil fuelled power plants as feedstock, the emission of CO2 and other GHGs is decreased,
3. 100% of the organic part of MSW can be eliminated in the Near-Zero-Emission (NZE) TCG-UC Green Energy Centers, in the "green electric energy" production process,
4. The coal mining industry could be "re-born" due to an option for NZE/CCT (Clean Coal Technology),
5. Several other issues – like the disposal of infectious and general hospital wastes, the wastes of the food and meat industry or the remains of dead animals – can also be addressed worldwide by using this very effective and green technology.

The recently-perfected TCG-UC plant is able to provide a solution to remedy these problems by utilizing both fossil energy source materials and organic waste material as feedstock to generate synthetic gas with high efficiency and near zero emissions, which can be utilized directly as fuel gas to generate electricity in a gas motor/turbine generator set (GenSet) or itself further processed as a feedstock to produce hydrocarbons such as ethanol, methanol, bio-diesel or synthetic natural gas (SNG) through the application of the well-known Fischer-Tropsch catalytic conversion system.

TCG-UC Plant is not merely one solution among the many, but is a special solution that provides the best presently available answer to the problems associated with the environmental contamination problems created for society by the huge volumes of MSW, the millions of used tires, and organic industrial waste handling and remediation. TCG units emit no harmful or toxic contaminants; the processing units have no chimneys, therefore during the conversion of the carbonaceous materials into syngas, the system has no materials emissions into the environment.

TCG technology is capable of converting any carbonaceous (organic) material (organic sludge, MSW); biomass; wood or grass; used tires; distillate, oil refinery or paper industry residues; fossil materials, or any mix of these materials) into a synthetic gas whose composition is controlled, without the uncontrolled emission of gas or liquid materials into the environment. The produced synthetic gas (SynGas) can be used directly in gas motor/generator sets to generate electricity or can serve as the feedstock for producing methanol, ethanol, diesel, jet fuel, synthetic natural gas, etc. (*Figure 1*).

TCG allows high temperature thermo-chemical gasification without oxygen and air. It incorporates several new technological developments and design features, such as:

- modular construction and shop fabrication;
- no requirement for refractory brick;
- no requirement for separation and injection of oxygen;
- no sensitivity to moisture content in the feedstock;
- no requirement for pulverization or slurry injection of feed;
- flexibility in feedstock alternatives, including varying proportions of coal, petroleum coke, biomass, sewer sludge or other organic waste in different proportions;
- utilization of a unique ionized water treatment system;
- near-zero air emissions and liquid discharge, along with the capability of recycling un-reacted carbons back into the reactor chamber.

In addition, some of the CO_2 – whether generated in the gasification process or from external sources – can be captured and recycled as feedstock. Furthermore, the potential exists to readily integrate this system into a portable, flexible gas-to-liquids bio-refinery.

The TCG-UC W2GE (Waste To Green Energy) System covers the whole problem area, offering a total setup: from the grinding machine, via the TCG Unit, to the SynGas-To-Electricity (GTE) Unit or the SynGas-To- Liquid (GTL)" Unit (using Fischer-Tropsch or other liquefaction technology) with specific and readily available additional equipment.

Verification of the technical parameters of the operating stage was carried out by independent organizations, including the Colorado School of Mines (CSM). The responsible department of energy (through the East Bay Municipal Utility District Department) requested a study in which a consulting firm, TSS Consultants (***http://www.tssconsultants.com***), summarized the potential and performance parameters - analysed by independent experts - of this thermo-chemical technology from a number of different angles. Five categories were examined: economic viability; energy efficiency; environmental compatibility; research, development, demonstration and deployment (RDD&D) evaluation stages; and potential socio-political effectiveness. These categories were selected and rated using data from several hundred installations worldwide, either currently operational or in the planning stages.

After lengthy investigation, the analysts deemed the TCG installation to be the most highly rated in the world and further recommended it to the United States Senate as one of the foremost methods available today for reducing the importance of fossil fuels in energy generation in the most environmentally-friendly and safest manner. In June, 2005, TSS Consultants concluded that "The thermo-chemical pyrolysis/steam reforming process when conducted in absence of oxygen or air is superior to all other existing technologies examined." Considering this study, the US House of Representatives, Science and Technology Committee, Subcommittee on Energy and Environment requested testimony on research and development issues for producing liquid fuels from coal on September 5, 2007.

According to the estimation of experts, GHG gas emissions could be decreased up to about 35-40% by installing TCG-UC CCT/W2GE power plants and – step-by-step – replacing the traditional coal-fired technology based power plants with this environmentally safe technology. The coal-fired TCG-UC CCT power plant and the W2GE power plant operate with these parameters if the feed material is coal, the efficiency of the process is much higher than incineration, it is not sensitive to moisture content and the quality parameters of the feed material, and there are no emissions, and the byproducts are waste heat (which can be used in agricultural and/or technical sidelines) and hot distilled water. This technology can be of great use in lowering GHGs and tackling other problems affecting our environment and economy.

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News corner:
Compiled by Isabel Fernández Fuentes and Anita Stein, EFG Office

Horizon 2020 projects

Horizon 2020 is the biggest EU research and Innovation programme ever, with nearly 80 billion euros of funding available to secure Europe's global competitiveness in the period 2014–2020. EFG is currently involved in seven Horizon 2020 projects: ¡VAMOS!, UNEXMIN, CHPM2030, FORAM, INFACT, INTERMIN and MINLAND. Below you will find descriptions of the topics and aims of these projects.

¡VAMOS!

642477 - VAMOS
¡Viable and Alternative Mine Operating System!
START DATE: 1 February 2015
DURATION: 42 MONTHS
http://vamos-project.eu

The aim of the EU-funded ¡VAMOS! (Viable Alternative Mine Operating System) project is to design and build a robotic underwater mining prototype with associated launch and recovery equipment, which will be used to perform field tests at four EU mine sites. The project consortium passed a major milestone in September 2015 with the successful delivery of conceptual design plans of the prototype and all associated equipment.

EFG's role:
EFG supports the project through stakeholder engagement and dissemination activities.

CHPM2030

654100 - CHPM
Combined Heat, Power and Metal extraction from ultra-deep ore bodies
START DATE: 1 January 2016
DURATION: 42 MONTHS
http://chpm2030.eu

The CHPM2030 project aims to develop a novel, pilot-level technology that combines geothermal resource development, minerals extraction and electro-metallurgy in a single interlinked process. In order to improve the economics of geothermal energy production, the project will investigate possible technologies for manipulating metal-bearing geological formations with high geothermal potential at a depth of 3–4 km in order to make the co-production of energy and metals possible; potentially this could be optimised according to market demands in the future. Led by the University of Miskolc (Hungary), the project will be implemented through the cooperation of 12 partners from 10 European countries.

EFG's role:
EFG supports the activities relating to the CHPM2030 methodology framework definition (WP1), particularly European data integration and evaluation: during the first months of the project, EFG's Linked Third Parties (LTP) have collected publicly available data at a national level on deep drilling programmes, geophysical and geochemical explorations and any kind of geo-scientific data related to the potential deep metal enrichments. They have also collected data on the national geothermal potential. Guidelines and templates for data collection were provided by EFG.

During the second year, EFG is supporting the road mapping and preparation for Pilots (WP6). EFG's Linked Third Parties will assess the geological data on suitable ore-bearing formations and geothermal projects collected in WP1, in relation with the potential application of the CHPM technology. This work will combine these data with the outcomes of the most recent predictive metallogenic models. Only existing datasets will be utilised; no new surveys will be carried out.

EFG also leads the Work Package on dissemination.

FORAM

730127 – FORAM
Towards a World Forum on Raw Materials
START DATE: 1 November 2016
DURATION: 24 MONTHS
http://foramproject.net/

The project Towards a World Forum on Raw Materials (FORAM) focuses on developing and setting up an EU-based platform of international experts and stakeholders to advance the idea of a World Forum on Raw Materials and enhance the international cooperation on raw material policies and investments. This platform will work on making the current complex maze of existing raw material related initiatives more effective. As such, the FORAM project is the largest collaborative effort for raw materials strategy cooperation on a global level so far. Synergies with relevant EU Member State initiatives are being explored and fostered. Particularly, the project seeks to engage the participation of G20 member countries and other countries active in the mining and other raw materials sectors in order to share experiences and increase understanding of all aspects of trade in raw materials.

The FORAM project is coordinated by the World Resources Forum Association (WRFA) and supported by eleven additional leading organisations (EuroGeoSurveys, European Federation of Geologists, United Nations University, Leiden University, University of Kassel, Clausthal University of Technology, ESM/Matsearch, Gondwana Empreendimentos e Consultorias, Servicio Geológico Colombiano, MinPol GmbH and La Palma Research Centre for Future Studies SL), which compose the FORAM consortium.

EFG's role:
EFG leads Work Package 3 on "Strategic Planning", which will set the stage for the World Forum on Raw Materials (WFRM) using a highly participative process. WP3 will define and present a long-term vision and its strategic positioning, as well as an appropriate framework to measure performance and to respond to geo-political, technological and economic changes.

UNEXMIN

690008 - UNEXMIN
Autonomous Underwater Explorer for Flooded Mines
START DATE: 1 February 2016
DURATION: 45 MONTHS
www.unexmin.eu

Thirteen organisations from seven countries across Europe are collaborating in this ambitious project to develop a submersible robotic system for surveying and exploring flooded mines. The €5 million project, funded by the European Union's Horizon 2020 research programme, will include the development of a Robotic Explorer (UX-1) for autonomous 3D mine mapping to gather valuable geological information that cannot be obtained in any other way; in general the mines are too deep and dangerous for access by human divers.

EFG's role:

Some of EFG's national associations participate in this project as Linked Third Parties and support the consortium through data collection for the inventory of flooded mines. EFG also supports the Work Package on dissemination and EFG's Third Parties disseminate the project results at national level in web portals, newsletters, conferences, workshops, educational activities, exhibitions or by any other relevant means.

INFACT

776487 – INFACT
Innovative, Non-invasive and Fully Acceptable Exploration Technologies (INFACT)
START DATE: 1 November 2017
DURATION: 36 MONTHS
www.infactproject.eu

Exploration discovery of raw material resources requires innovations that change the geological targets of exploration, the physical places that are reached, or the manner in which they are explored. Despite its rich history of mining and residual mineral wealth, current conditions within the EU present a number of social, political, legislative, cost, technical and physical obstacles to raw material exploration: obstacles to be overcome by innovation, dialogue and reform.

The Innovative, Non-invasive and Fully Acceptable Exploration Technologies (INFACT) project unites stakeholders of Europe's future raw materials security in its consortium and activities. Via effective engagement of civil society, state, research and industry, the project will focus on each of these obstacles. It will co-develop improved systems and innovative technologies that are more acceptable to society and invigorate and equip the exploration industry, unlocking unrealised potential in new and mature areas.

The project will develop innovative geophysical and remote sensing technologies (less-invasive than classical exploration methods) that promise to penetrate new depths, reach new sensitivities and resolve new parameters.

The project will also set the EU as a leader on the world stage by establishing permanent infrastructure to drive innovation in the next generation of exploration tools: tools that are cost-effective, designed for EU conditions and its raw materials strategy, and high-performing in terms of environmental impact, social acceptability, and technical performance.

INFACT is comprised of the following main components:

- Development and test of innovative, non-invasive exploration technologies.
- Foundation of three test sites for exploration technology in the south, centre and north of Europe.
- Stakeholder engagement, education and policy reform.

These actions combine to reach each of the main areas in which the EU has the power to influence change in its raw materials security.

EFG's role:

EFG leads the work package on dissemination and impact creation and several of the Federation's National Associations are actively involved in the project as Linked Third Parties.

MINLAND

776679 – MINLAND
Mineral resources in sustainable land-use planning
START DATE: 1 December 2017
DURATION: 24 MONTHS

Access to mineral resources in Europe is one of the pillars of the Raw Materials Initiative (RMI). Yet, competing societal interests, such as expanding cities, infrastructure development, agriculture and nature conservation, have had negative effect on the available area for exploration and mining of mineral resources. Consequently, the supply of mineral raw materials within the EU is at risk. Therefore, the integration of mineral resources policies into land-use planning at different scales and levels is a key factor for achieving the goals of the RMI.

The MinLand project is designed to address this challenge: to facilitate minerals and land-use policy making and to strengthen a transparent land use practice. MinLand is composed around the acknowledgement that the call requires a broad and competent consortium with strong links to related projects and activities, a comprehensive and structured data repository, an efficient work flow and strong and broad stakeholder involvement.

EFG's role:

EFG supports the activities for valorisation and valuation of geological and societal data and civil society impacts. It will also be involved in the network and clustering activities and in the communication, dissemination and exploitation of the project.

INTERMIN

776642 – INTERMIN
INTERNATIONAL NETWORK OF RAW MATERIALS TRAINING CENTRES
START DATE: 1 February 2018
DURATION: 36 months

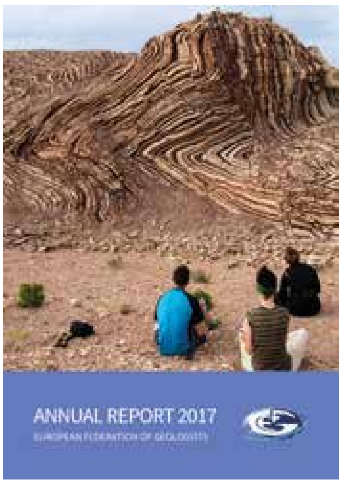
INTERMIN will create a feasible, long-lasting international network of technical and vocational training centres for mineral raw materials professionals. Specific objectives:

- Develop common metrics and reference points for quality assurance and recognition of training;
- Develop a comprehensive competency model for employment across the primary and secondary raw materials sector;
- Introduce an international qualification framework for technical and vocational training programmes;
- Create a conceptual framework for the development of joint educational training programmes based on present and future requirements by employers;
- Create and launch a joint international training programme by a merger of competences and scope of existing training programmes.

EFG's role:

EFG is cooperating with the project partners in 6 work packages, and in WP3 (Towards enhanced training programmes (Response)) EFG is acting as the leader. The INTERMIN project aims at mapping, connecting and enhancing the existing European training and education initiatives in the raw material sector. Therefore, the INTERMIN consortium aims at creating a self-sustainable international network of specialised training centres for professionals from the raw materials sector, and BDG (Berufsverband Deutscher Geowissenschaftler e.V.) will participate in the INTERMIN project as a third party of EFG. The Polish Association of Minerals Asset Valuators (PAMAV) is also involved in the project as an EFG Linked Third Party.

EFG Annual report 2017



The European Federation of Geologists (EFG) is pleased to present its Annual Report for the past year. 2017 was indeed the last year of EFG's Strategic Plan for the period 2014 to 2017 and the annual report presents the main outcomes for each of the strategy's seven action plans: supporting EFG Members, European Network, Global Network, EurGeol as Competent Person, Services, Projects and Communication.

In 2017, among others:

- EFG succeeded in expanding its membership basis by welcoming a new full member, the EurAsian Union of Experts in Subsoil in Subsurface Management (EUES), based in Russia.
- EFG also extended its Panels of Experts platform by creating a new Panel on Geotechnics. EFG now has 10 panels focusing on the topics CO2 Geological Storage, Education, Geoheritage, Geothermal, Geotechnics, Hydrogeology, Minerals, Natural Hazards, Oil and Gas, and Soil Protection, with a total of 222 experts from 22 European countries.
- Moreover, EFG enlarged its international network with other organisations. In this context, collaboration agreements have been signed with the European Association of Geoscientists and Engineers (EAGE), the Geological Society of Korea (GSK), the United Nations Framework Classification for Resources (UNFC) and the Young Earth Scientists (YES) network.
- The European Geologist professional title continued to gain popularity. Since its creation, nearly 1,478 titles have been awarded in total and 987 titleholders are currently active and in good standing with EFG
- EFG is currently involved in 10 projects funded under the EU's Horizon 2020 programme, some of which also count on the active participation of EFG's national associations, which are involved as Linked Third Parties (LTPs).

You can read a full report about EFG's activities in 2017 here: ***https://eurogeologists.eu/wp-content/uploads/2018/05/annual_report_2017_final_20180524.pdf***

EFG Board Elections and a new full member

The 2018 Spring Council Meeting was conducted in Çesme (Turkey) on 19–20 May 2018. During the morning of the second day, the application of the Romanian National Association of Professionals in Geology and Mining was approved by the National Associations' delegates. The Romanian colleagues presented their association and expressed their excitement at becoming part of the European family of geologists.

Later, elections for two open positions of the EFG Board were held. There were two candidates for Secretary General: Gabriele Ponzoni from the Italian association (CNG) and Carlos García Royo from the Spanish association (ICOG). Both presented their candidacies to the National Associations delegates, who voted for their preferred candidate. As a result, Gabriele Ponzoni was re-elected Secretary General.

For the Vice President position, Michael Neumann from the German Association (BDG) was the only candidate and was approved by the delegates participating in the Council.

Submission of articles to European Geologist Journal

Notes for contributors

The Editorial Board of the European Geologist journal welcomes article proposals in line with the specific topic agreed on by the EFG Council. The call for articles is published twice a year in December and June along with the publication of the previous issue.
The European Geologist journal publishes feature articles covering all branches of geosciences. EGJ furthermore publishes book reviews, interviews carried out with geoscientists for the section 'Professional profiles' and news relevant to the geological profession. The articles are peer reviewed and also reviewed by a native English speaker.
All articles for publication in the journal should be submitted electronically to the EFG Office at ***info.efg@eurogeologists*** according to the following deadlines:

- Deadlines for submitting article proposals (title and content in a few sentences) to the EFG Office (***info.efg@eurogeologists.eu***) are respectively 15 July and 15 January. The proposals are then evaluated by the Editorial Board and notification is given shortly to successful contributors.
- Deadlines for receipt of full articles are 15 March and 15 September.

Formal requirements

Layout

- Title followed by the author(s) name(s), place of work and email address,
- Abstract in English, French and Spanish,
- Main text without figures,
- Acknowledgements (optional),
- References.

Abstract

- Translation of the abstracts to French and Spanish can be provided by EFG.
- The abstract should summarise the essential information provided by the article in not more than 120 words.
- It should be intelligible without reference to the article and should include information on scope and objectives of the work described, methodology, results obtained and conclusions.

Main text

- The main text should be no longer than 2500 words, provided in doc or docx format.
- Figures should be referred in the text in italic.
- Citation of references in the main text should be as follows: 'Vidas and Cooper (2009) calculated…' or 'Possible reservoirs include depleted oil and gas fields… (Holloway *et al.*, 2005)'. When reference is made to a work by three or more authors, the first name followed by '*et al.*' should be used.
- Please limit the use of footnotes and number them in the text via superscripts. Instead of using footnotes, it is preferable to suggest further reading.

Figure captions

- Figure captions should be sent in a separate doc or docx file.

References

- References should be listed alphabetically at the end of the manuscript and must be laid out in the following manner:
- Journal articles: Author surname, initial(s). Date of publication. Title of article. Journal name, Volume number. First page - last page.
- Books: Author surname, initial(s). Date of publication. Title. Place of publication.
- Measurements and units
- Measurements and units: Geoscientists use Système International (SI) units. If the measurement (for example, if it was taken in 1850) was not in SI, please convert it (in parentheses). If the industry standard is not SI, exceptions are permitted.

Illustrations

- Figures should be submitted as separate files in JPEG or TIFF format with at least 300dpi.
- Authors are invited to suggest optimum positions for figures and tables even though lay-out considerations may require some changes.

Correspondence

All correspondence regarding publication should be addressed to:
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Rue Jenner 13, B-1000 Brussels, Belgium.
E-mail: ***info.efg@eurogeologists.eu***

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Advertisements

EFG broadly disseminates geology-related information among geologists, geoscientific organisations and the private sector which is an important employer for our professional members, but also to the general public.

Our different communication tools are the:

- EFG website, ***www.eurogeologists.eu***
- GeoNews, a monthly newsletter with information relevant to the geosciences community.
- European Geologist, EFG's biannual journal. Since 2010, the European Geologist journal is published online and distributed electronically. Some copies are printed for our members associations and the EFG Office which distributes them to the EU Institutions and companies.

By means of these tools, EFG reaches approximately 50,000 European geologists as well as the international geology community.

With a view to improving the collaboration with companies, EFG proposes different advertisement options. For the individual prices of these different advertisement options please refer to the table.

Prices for advertisements

EGJ	**One Insertion**	**Two Insertions**
Full page (colour)	820 Euro	1320 Euro
Half page (colour)	420 Euro	670 Euro
Quarter page (colour)	220 Euro	350 Euro
Full page (black and white)	420 Euro	670 Euro
Half page (black and white)	220 Euro	350 Euro
Quarter page (black and white)	120 Euro	200 Euro
Business card size	90 Euro	150 Euro
Preferential location	25% plus	
Price for special pages:		
Outside back cover (colour)	1200 Euro	1900 Euro
Second page (colour)	1000 Euro	1600 Euro
Second last page (colour)	1000 Euro	1600 Euro

Geonews	**Annual Price**
Ad and regular newsfeed	1500 Euro
EFG Homepage	
Ad and regular newsfeed	1500 Euro
University ad	
Ad for training opportunities in the job area of the homepage	500 Euro
Annual package	
Business card size ad in EGJ, GeoNews and homepage.	3000 Euro