Desktop Review of African Geological Survey Organisation Capacities and Gaps

African Minerals Development Centre

United Nations
Economic Commission for Africa

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Executive summary

The African Minerals Development Centre (AMDC) is implementing the Africa Mining Vision (AMV), which was adopted by African Heads of State at the twelfth ordinary session of the Assembly of the African Union, in February 2009. The Geological and Mining Information System is a key cluster of the Action Plan for the Implementation of AMV (2012). Geological survey organisations (GSOs) in Africa are important to the success of AMV and any work on geological information. As such, this report aims to make an initial assessment of the capacity of African GSOs relative to the geological information needs of each country and identify some next steps for AMDC and its partners (from within and outside of Africa) to take to address gaps. The report and its findings are based on a literature review of existing capacity assessments of African GSOs and a desktop gap analysis of geological information needs relative to the information available from African GSOs.

The literature review and gap analysis show that most African GSOs are deficient in capacity and geological information. This limits the ability of African countries to reach their minerals and development potential; it may also limit the sustainability of mineral related income to various African countries. Nearly half of all African economies rely on mining, quarrying and petroleum for 5 per cent or more of their measured GDP, yet at the same time "African states lack basic geological mapping or, at best, are poorly mapped", according to AMV (AMV, 2009, p.15). In fact, only six African GSOs were rated by Geoscience Australia (Kay and others, 2012) as having either a strong capacity (South Africa) or the "capacity to undertake major geoscientific surveys and disseminate data efficiently" (Egypt, Ethiopia, Morocco, Namibia and the United Republic of Tanzania). All other countries were rated as either having some capacity, limited capacity, or no information or GSO was detected. From these results, it is clear that many African countries that have existing minerals industries are risking the sustainability of these industries due to a lack of public geological information and the need for adequate policies, legislation, regulation, licensing and minerals practices. Furthermore, other countries with the potential for minerals development are postponing the establishment of artisanal and small scale mining (ASM)1 development and industrial scale minerals development due to a lack of geological information.

GSOs typically provide information on minerals, energy resources, hydrogeological resources and geological hazards. While the primary focus of AMDC is on minerals information for development, geological mapping, geophysical and other data collections may have secondary co-benefits when it comes to understanding renewable and non-renewable energy resources, hydrological and hydrogeological systems, geohazards and geotechnical issues. There may be significant development co-benefits associated with information gathered by GSOs to better understand minerals systems.

The relationship between minerals information and development is complex. For example, investments that seek to enhance information on minerals might include:

- Minerals information that attracts investment in industrial and artisanal mining leading to better resource rents, which coupled with good governance can be used to contribute to public services and infrastructure investment;

- Energy information that can help countries extend or initiate petroleum exploitation, or help identify new renewable hydro-electricity resources and geothermal energy to power industries, agricultural activities including irrigation, and households;

- Hydrogeological and hydrological information that can be used to find new water resources

1 In many cases, artisanal and small-scale miners do not refer to data from GSOs, however, permitted small- scale mining of industrial mineral deposits can benefit from greater earth sciences knowledge, particularly of where such deposits might exist.

in water scarce areas and better manage water resources for agriculture, mining, electricity and other uses in all countries;

- Data on hazards and geotechnical information that can be coupled with planning processes to improve the resilience of development.

Given the potential development benefits that can come from improving geological information, AMDC is taking a strategic approach when working with GSOs and other partners to maximise potential benefits of geological data. This includes looking at how to improve information management systems and the application of standards so that data from multiple sources can be integrated and used to form a coherent understanding of minerals, as well as supporting the understanding of other geological resources and hazards. For individual member States, national spatial data infrastructure (NSDI) plays an important role in helping to set standards and facilitating the wider integration of geological data for development.

From the gap analysis, it is apparent that different countries have very different geological information needs in the areas of minerals, energy, hydrogeology and hazards, and varying levels of capacity and information available in each of these areas. As such, AMDC aims to address GSO capacities on a case by case basis. If member States request support, AMDC and other partners from within and outside Africa can collaborate with GSOs by reviewing:

- Institutional arrangements;
- Existing capacities and areas for improvement;
- Data management systems and standards, including the reporting from mining companies;
- Technologies used and potential upgrades;
- Existing data, data needs and data gaps;
- Potential data acquisitions to address data gaps.

The challenges faced by GSOs in Africa are not necessarily unique to Africa or to any one country within Africa. It is important, therefore, for AMDC to compile GSO best practices from within Africa and abroad, thus allowing comparison of systems and experiences. Best practices may be adopted and adapted by GSOs to meet their own needs.

This report is an important input into the geology and mining information systems workstream and strategy of AMDC. For more information on areas of focus, next steps and the role of AMDC and other partners in geology and mining information systems, please contact AMDC.

1 Introduction

Africa Mining Vision

The Africa Mining Vision (AMV) was adopted by the African Union in February 2009following the October 2008 meeting of African Ministers responsible for Mineral Resources Development.[2] As stated in AMV, "African states lack basic geological mapping or, at best, are poorly mapped" (AMV, 2009, p.15). It was noted that both the level and quality of mineral resource potential data are key issues for realizing AMV, especially since the quality and coverage of resource data affect the ability of African countries to attract investors and negotiate favourable resource rents for the country, and that investments in basic geological and geophysical data can pay for itself many times over due the resources and economic activity that might be attracted to a country's minerals sector (AMV, 2009).

African Minerals Development Centre and geological survey organizations

The African Minerals Development Centre (AMDC) is implementing AMV. The Geological and Mining Information System is a key AMDC workstream. The first activity being conducted in this workstream is a desktop review of the capacity of geological survey organizations (GSOs) in Africa, along with a gap analysis. The gap analysis looks at the level of need for types of geological information and then compares this with indicators of what geological information is available. Based on the gap analysis, steps for supporting minerals information are proposed for AMDC and partners to engage in.

This review of capacities and gap analysis is based on a desktop study of existing literature on the status of 50 GSOs found across 54 countries in Africa (see Table 1) coupled with indicators drawn from international sources. The review is one of several inputs that will feed into the development of AMDC strategy for improving African GSO capacities to embark on exploration activities, which will identify entry points for AMDC to engage in this area with stakeholders and partners.

2 See http://www.africaminingvision.org/about.html

Table 1: Geological survey organizations from across Africa

Country	Survey name
Algeria	Service Geologique National Algeria
Angola	Direccao de Servicos de Geologia
Benin	Office Béninois des RecherchesGéologiques et Minières
Botswana	Department of Geological Survey
Burkina Faso	Bureau des Mines et de la Geologie du Burkina
Burundi	Directorate General of Geology and Mines
Cameroon	The Institute for Geological and Mining Research
Cabo Verde	Ministerio do ambiente, agricultura e pesca
Central African Republic	Ministere des mines de l'energie et de l'Hydraulique
Chad	Direction des Mines et de la Géologie
Comoros	Recherche de la Minière
Côte d'Ivoire	Direction des Mines et de la Géologie
Democratic Republic of the Congo	Centre de RechercheGéologique et Minière
Djibouti	InstitutSupérieurd'Études et de RecherchesScientifiques et Technique
Egypt	Egyptian Mineral Resources Authority , Sector of Geological Survey
Equatorial Guinea	Department of Mines and Hydrocarbons
Eritrea	Ministry of Land, Water and Environment
Ethiopia	Geological Survey of Ethiopia
Gabon	Ministère de l'agriculture, de l'élevage et du développement rural
Gambia	Geological Department Office of the President
Ghana	Geological Survey Department Ghana
Guinea	Ministry of Mines and Geology Guinea
Guinea-Bissau	Secrétariatd'Etat de l'Industrie, des RessourcesNaturelles et de l'Environement
Kenya	Mines and Geological Department of Kenya
Lesotho	Department of Mines & Geology
Liberia	Liberian Geological Survey
Libya	Geological Research and Mining Department
Madagascar	Service de la Géologie
Malawi	The Geological Survey Department of Malawi
Mali	Direction Nationale de la Geologie et des Mines
Mauritania	Service Géologique
Mauritius	
Morocco	
Mozambique	National Directorate of Geology
Namibia	Geological Survey Department, Ministry of Mines and Energy
Niger	Geological Survey in Niger
Nigeria	Nigerian Geological Survey Agency
Congo	Ministère des mines, de l'énergie et de l'hydraulique
Rwanda	Rwanda Geology and Mines Authority
Sao Tome and Principe	Ministère des ressourcesnaturelles et de l'environnement
Senegal	Direction of Mines and Geology
Seychelles	
Sierra Leone	Geological Survey Division
Somalia	Geological Survey Department
South Africa	Council for Geoscience
South Sudan	

Country	Survey name
Sudan	Geological Research Authority of the Sudan
Swaziland	Geological Survey and Mines Department
Togo	Direction Générale des Mines et de la Géologie
Tunisia	Office National des Mines
Uganda	Geological Survey and Mines Department Uganda
United Republic of Tanzania	Geological Survey of Tanzania
Zambia	Geological Survey Department
Zimbabwe	Zimbabwe Geological Survey

Source: Kay, and others (2012).

Outline of the report

Following the executive summary and introduction in chapter 1, chapter 2 reviews GSO related research with specific attention to on a study of Africa's natural resources and related institutions requested at the first session of the Economic Commission for Africa (ECA), GSO research on East Africa in 1965, a British Geological Survey (BGS) study in the 1990s, and recent assessments from Geoscience Australia and EI Source Book respectively in 2012. Chapter 2 also presents a case study from Zambia and a study of fundamental datasets for Africa, and then summarizes spatial data infrastructure in Africa in the context of integrating geological data with other data for wider development benefits.

Chapter 3 sets out the methods and data sources used for the gap analysis and assesses both the need for geological information and the capacity of GSOs in the areas of minerals and mining, energy, hydrogeology and geological hazards. Chapter 3 also examines the effectiveness of capacity-building and GSO support in terms of GSO capacities.

Chapter 4 draws together information from the literature review and gap analysis to provide a discussion of geological information systems and development, minerals data needs and gaps in capacities, and other data needs and gaps related to GSOs. Chapter 4 also discusses how to fill gaps, the effectiveness of GSO support to date, the role of spatial data infrastructure and standards as well as wider development applications of geological data.

Chapter 5 makes conclusions regarding GSO capacities, the issues faced by GSOs and sets out some next steps for AMDC based on these conclusions.

2

Review of GSO capacity related studies

2.1 Introduction

Numerous studies have focused on the capacities and general functions of GSOs and the ways in which partners work with and support GSO capacities. As a point of departure, the present study reviewed GSO and related capacity studies in Africa, including:

- A study by the United Nations Educational, Scientific and Cultural Organization (UNESCO), requested by ECA, on geology resource information in Africa from 1963;
- A summary of the status of geological mapping in East Africa from 1965;
- A study by BGS of geological surveys in developing countries and strategies for assistance (see Reedman, and others 1996);
- An assessment of mineral potential, geosciences survey capacity, risk and geological aid in Africa, Asia, Latin America and the Pacific (published in 2012 by Geoscience Australia);
- An EI SourceBook assessment of geodata for development, including GSO capacities and possible options related to data (published in 2013);
- The Geological Survey of Zambia, a 2013 case study on geological and minerals information systems.

In addition to GSO related information, spatial data infrastructure and related issues are also reviewed, including:

- A review of fundamental spatial datasets for Africa (ECA, 2007);
- A summary of African progress on spatial data infrastructures.

Other studies related to GSOs and spatial data infrastructures were either not publicly available or were not accessible in English. Consequently, the desktop review was limited to examples that surfaced via a literature search using key words in English.

2.2 A review of the natural resources of the African continent (1963)

A report by UNESCO entitled "A review of the natural resources of the African continent" begins as follows:

> "At the end of its first session, held at Addis Ababa from 29 December 1958 to 6 January 1959, the Economic Commission for Africa reported that it 'considered that there was a great need in Africa for certain types of scientific surveys such as hydrological, geological, geodetic and other surveys of resources including resources for industrialization and sources of energy such as solar energy.' According to this same report, 'the view was expressed that as part of this work the Secretariat might compile a bibliography of surveys already carried out and draw attention to major gaps'" (see UNESCO, 1963).

The report summarised information on Africa's natural resources and included a chapter on "Geology, applied geology (mineral resources) and geophysics in Africa", prepared by Frank Dixey, the president of the Association of African Geological Surveys, in which he delineated the role of geological surveys along with the state of geological information across Africa (see Dixey, 1963). Dixey also sketched the role that institutions (e.g. GSOs, ministries of mines, mining companies and universities) must play in order to generate and host geological information.

On the role of geological surveys, Dixey (1963) noted that geological surveys engage in fundamental research on geology that forms a basis for future minerals exploration. Dixey further noted that fundamental geological information is essential to support infrastructure development, groundwater development and agriculture. Dixey emphasized that minerals information can regard minerals for local use or export, such as limestone and clays for cement, ceramic and brick manufacturing.

Geological information was said to be "patchy", based on the research taken to prepare the geological bibliography for Africa. It was noted that, prior to the First World War, the geology of the British overseas territories was virtually unknown, and that after the First World War the need for materials led to each of the territories receiving between one to five geologists. These geologists mainly undertook reconnaissance work as there was a lot of territory to cover and very few staff. Pre-colonial mining sites and abandoned workings, even in very remote areas, were noted as helping reconnaissance missions identify areas of minerals potential.

After the Second World War, the need to find materials with which to rebuild Europe led to a fourfold increase in the number of geologists engaged in geological and topographical mapping. Topographic maps and aerial photos facilitated progress on geological mapping, but despite these developments, Dixey noted that even at the mapping scale of 1:250,000, it would take 30 or more years for some countries to achieve complete coverage.

Dixey (1963) provided a summary of mapping and coverage for a number of areas in Africa. Madagascar was highlighted as having completed geological maps at 1:200,000 scale, which provided full coverage of the country. Dixey further noted that more mapping of the country was ongoing at more detailed scales. Swaziland also had full geological coverage, but at scale of 1:50,000. The Republic of South Africa was noted as having only 24 per cent geological map coverage in 1952 at 1:125,000 or better resolutions. Similarly, in what was then Southern Rhodesia, there was only 26 per cent coverage by detailed geological maps in 1956. That was, however, a significant improvement on the 16 per cent coverage just five years earlier. To put these figures into perspective, Dixey noted that in Great Britain where geological mapping had been ongoing for 125 years, there was still another 25 per cent of the territory to be geologically mapped at the 6 inches to the mile (i.e. 1:10,560) scale, although mapping had been completed at the inch to the mile (i.e. 1:63,360) scale.

Dixey (1963) also discussed progress in geophysical surveys, radiometric surveys and geochronology in Africa, along with significant mineral deposits that had been found and areas of future minerals potential. However, from the summary it was clear that large areas were yet to be covered.

Table 2: Staff levels for African geological surveys or related organisations

Territory or region	Year or period	Staff numbers
Republic of South Africa	1910 (Founded)	80 geologists and scientific officers
Southern Rhodesia	1910 (Founded)	12 staff
Nigeria	1919 (Founded)	30 staff
French West Africa (A.O.F.) – Office based in Dakar	1930 (Founded)	45 geologists 35 assistant geologists
Sudan	Pre-WWII	3 officers
British Overseas Geological Surveys (covering: Uganda, Kenya, Tanganyika, Northern Rhodesia, Nyasaland, Bechuanaland, Swaziland, Somaliland Protectorate, Nigeria and Sierra Leone)	Post-WWII	130 scientific staff
Algeria	1947	12 geologists
Algeria	1954	30 geologists and geophysicist
Ghana	1957-1958	24 geologists
Liberia	1959	5 geologists 2 mining engineers 1 chemist 6 photogrammetrists 1 aerial photographer 1 pilot.
French Equatorial Africa (A.E.F) -Office based in Brazzaville	Pre 1960	28 geologists 40 prospectors
Cameroon	Pre 1960	8 geologists
Madagascar	Pre 1960	15 geologists
Federation of Rhodesia and Nyasaland (i.e. geological surveys of Salisbury, Lusaka and Zomba)	~ 1960	30 geologists in total Other staff include geophysicists and chemists
Republic of South Africa	~ 1960	80 qualified officers as well as links to 8 universities with geological departments
Morocco	~ 1960	180 staff, of which 40 geologists 8 geological technicians
United Arab Republic	~ 1960	57 geologists 14 chemists 10 geophysicists 10 engineers
Sudan	1962	24 specialists, including: 20 geologists 1 geophysicist 1 chemist
Total for sub-Saharan Africa employed by the State	~ 1960	400 geologists (excluding geologists employed by parastatal bodies)
Total for sub-Saharan Africa employed by the State	~ 1960	500 geologists (including geologists employed by parastatal bodies)
Total specialists for sub-Saharan Africa including those employed by the private and public sectors	~ 1960	830 specialists (based on a list compiled by the Inter-African Geological Correspondent)

Source: Dixey (1963).

Dixey (1963) discussed the capacity of GSOs. According to Dixey (1963), geological surveys with over 20 staff were considered large. At that time, most professional staff members were expatriates. It was observed that some professions, such as law and medicine, had attracted African students, but geology had not attracted many African students. The exception to this was Egypt where local staff had for a long time filled all types of positions.

Dixey (1963) provided information on the capacities of GSOs and related organisations that had fulfilled GSO type functions. Table 2 summarises this information presenting staff level figures by countries and institutions over time. The difficulty in obtaining suitably qualified local staff for professional posts was noted, including the need for staff to have proper academic qualifications and an aptitude for field work (e.g. the ability and willingness to spend significant periods of time out in the field). It was recommended that capable technicians be identified and sent for more training in order to become qualified, rather than providing geology scholarships for untested students who would eventually be expected to join a GSO. Examples of such approaches and in-house training were given for the Congo, Ghana, Madagascar, Nigeria, Senegal and Sierra Leone (see Dixey, 1963).

The need for less well equipped GSOs to partner with better equipped and experienced GSOs was noted along with the need for intra-African training, for example at universities with well-established geology programmes. The role of universities in undertaking geological research was also noted, including universities from within and outside of Africa. The role of geological societies and other types of associations was acknowledged, especially with regard to the sharing of knowledge and information.

Dixey (1963) made a series of recommendations. With regard to geological surveys and their capacities Dixey stated "In the relatively well-developed territories, the greatest need probably relates to improved salary and other conditions so as to attract and retain geologists, palaeontologists, chemists, geophysicists and other scientific officers of the official geological surveys and bring their establishments up to strength" (Dixey, 1963, p.82). Other recommendations focused on the need for a geologist to have a good honours degree with at least five years of field experience before being allowed to map independently. Dixey noted that the most valuable minerals are found in basement rocks and suggested that new geological surveys should focus on basement rocks. Dixey also pointed out the need to link with universities and to share information across borders, for example through conferences and other meetings. Dixey (1963) highlighted the need to look at minerals that can be used as an input for local manufacturing and development (including fertilisers) and made recommendations on minerals regimes to encourage prospecting and minerals development.

Dixey had many other interesting insights and observations including an important statement on the context in which the report was written in 1963:

> "As a result of increasing population and rising standards of living, not only in Africa but throughout the world, ever-increasing quantities of minerals will be required, and to keep pace with these new demands as well as to replace the deposits now being worked as they become exhausted, the search for new sources must continue with an ever greater intensity" (Dixey, 1963, p.54).

The same might be said today.

2.3 Geological mapping in East Africa (1965)

Temple (1965) reviewed the status of mapping in East Africa, specifically mapping in Kenya, Uganda and the United Republic of Tanzania. His review found that broad mapping activities had taken place at the scales of 1:10,000,000, 1:4,000,000 and 1:2,000,000. There had also been significant mapping at standard scales of 1:100,000 and 1:125,000 (see Table 3). However, Temple also found that 37 per cent of Kenya, Uganda and the United Republic of Tanzania had not been geologically mapped as of 1965. Temple noted that his study did not attempt to assess the quality of the maps produced and that coverage is only one dimension. It should, however, be noted that the quality of mapping and metadata is another dimension that has a strong bearing

Table 3: Comparison of regional geological mapping

		Unmapped geologically		Standard scale mapping (1:100,000 and 1:125,000)		Unpublished mapping		Older mapping	
Country	**Total land area (square miles)**	**Area (square miles)**	**%**	**Area (square miles)**	**%**	**Area (square miles)**	**%**	**Area (square miles)**	**%**
Kenya	219790	48365	22	79458	36	82392	38	9975	4
United Republic of Tanzania	342170	153736	45	77177	23	87522	26	23735	7
Uganda	80301	32851	41	24557	30	21370	27	1523	2
East Africa	642261	234952	37	181192	28	191284	30	34833	5

Source: Temple, 1965.

on how maps are interpreted and how accurately they reflect underlying geological conditions.

For a map of the geological map coverage of Kenya, Uganda and the United Republic of Tanzania in 1965, see Figure 18 in annex 1 to the present document.

2.4 BGS study of developing country GSOs (1996)

BGS examined GSOs around the world (see Reedman and others 1996). Thirty one countries returned detailed questionnaires, of which 10 were from Africa: Angola, Botswana, Egypt, Ethiopia, Gambia, Ghana, Malawi, Namibia, Zambia and Zimbabwe.

2.5 GSO core functions

The study by BGS included an assessment of the role of geological surveys and their core functions (i.e. programmes). The key findings are summarised in annexes 3 (Table 14) and 4 (Table 15) to the present document. The study reviewed the current status of GSOs and set out possible ideas for technical assistance in the future.

With regard to the functions of GSOs, it was noted that:

> “Virtually all national GSOs were founded with the prime objective of carrying out systematic, nationwide surveys of the geology of the nation in order to determine the national potential for wealth creation through the exploitation of georesources” (Reedman, and others 1996, p.5).

GSOs from Africa were found to be lagging behind GSOs from other regions in terms of the map coverage of their territories and the capacity to engage in geological surveys.

2.5.1 GSO data and development

According to Bernknopf, and others (1993, p.1), “Detailed, publicly available information concerning the nature and origin of the geology of an area is essential for informed public-policy decision-making and for economic development.”

Table 4: Uses of geological information from GSOs

	Geological Mapping	Geomorphology (Bathymetry)	Geochemistry	Geophysics	Hydrogeology	Metallic Minerals genesis	Non-Metallic Minerals genesis	Gem & Precious Metals Exploration	Petroleum Geology	Geothermal Studies	Nuclear Geology	Marine Geology	Geotechnical Engineering	Remote Sensing	GIS/IT
1 Minerals aggregates extraction	X	X			X		X	X				X	X	X	X
2 Minerals industrial extraction	X		X	X		X	X					X	X		X
3 Waste management	X	X	X		X						X	X	X		X
4 Environmental assessment	X	X	X		X					X	X	X	X	X	X
5 Planning (old workings, caverns, landslips)	X	X			X						X	X	X	X	X
6 Coastal management (erosion, sedimentation)	X	X	X		X						X	X	X	X	X
7 Water management resources (groundwater)	X	X	X	X	X					X	X			X	X
8 Water management protection	X		X		X					X	X				X
9 Construction industry, (building foundations, among others)	X												X		X
10 Road, rail, canal, airport, dock, (transport) construction	X				X							X	X	X	X
11 Insurance industry (subsidence, earthquake, among others)	X												X	X	X
12 Education requirements	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
13 Academic research areas	X	X	X	X	X	X	X	X	X	X	X	X		X	X
14 Hydrocarbons offshore industry	X		X	X					X			X	X	X	X
15 Hydrocarbons onshore industry	X		X	X	X				X				X	X	X
16 Coal mining	X			X	X								X	X	X
17 Health	X		X		X	X	X				X				X
18 Conservation	X	X			X								X	X	X
19 Tourism, recreation, adornment	X	X						X					X	X	X
20 Agriculture	X				X									X	X
21 Forestry	X				X									X	X
22 Military (onshore)	X	X		X	X				X		X	X	X	X	X
23 Military (offshore)	X	X		X					X		X	X	X	X	X
24 Communications (e.g. seafloor cables, power lines, tunnels)	X	X		X								X	X		X
25 Geothermal power	X			X	X	X	X			X			X	X	X
26 Nuclear minerals industry and radioactivity considerations	X	X	X	X	X	X					X		X	X	X
27 Metallic minerals industry	X	X	X	X	X	X		X			X	X	X	X	X
28 Gemstones	X	X	X	X				X					X	X	X
29 Equipment manufacture, survey and mining				X	X	X			X	X	X	X			X
30 Offshore equipment				X					X			X	X		X
31 Global environment, relative sea level change		X			X	X				X	X	X	X	X	X
32 Minerals and petroleum law administration						X	X		X	X	X	X	X	X	X

Source: Reedman, and others (1996).

Reedman and others (1996) reviewed cost benefit analyses of information from GSOs in numerous countries, including information from GSOs in developing countries, and noted that better geological information can positively impact several areas, such as minerals, groundwater, energy, hazards and planning, and other potential applications, among others (see Table 4). The same researchers, however, pointed out that it can be difficult to value how much benefit is from geological information versus other inputs. Benefits, in many cases, are related to avoidance of costs (e.g. better planning or avoidance of disasters related to hazards), but in the case of resources immediately measureable benefits relate to mineral resources being discovered (i.e. forming a new asset) and new economic activity being generated around resources.

One of the examples provided centred on a geological mapping project (funded by the United Kingdom of Great Britain and Northern Ireland) that was carried out during a BGS study between 1980 and 1987 in Kenya. Following the project, a cost benefit analysis was conducted which found a geological map had net benefits of over £200,000 per year, assuming a map has a lifespan of more than 40 years before the areas covered needs to be remapped. It was concluded "that the mapping project had made, and would continue to make, significant beneficial impacts in a number of different sectors" (Reedman, and others 1996, p.38). However, from the information provided in the analysis it is hard to judge the accuracy or validity of the estimate. Importantly, the authors, in a subsequent publication, went into more detail regarding the value of GSOs and provided detailed case studies on minerals and groundwater (see Reedman, and others 2002).

2.5.2 Map coverage

In the study by BGS, it was found that only 46 per cent of the total aggregate area in the 10 African countries that responded to the survey had been geologically mapped at scales better than 1:250,000 and that a significant fraction of these surveys had not been published. Malawi had, however, mapped its entire territory at scales better than 1:250,000.

2.5.3 GSO capacity

One way of looking at GSO capacities is to assess the number of staff relative to the area that needs to be mapped. BGS showed that 10 GSOs in Africa in 1995 had a total of 995 available graduates and a land area of 6.25 million km^2, of which 54 per cent was unmapped. It was noted that "The ratio for the African and European Union GSOs are 1 graduate per 6294 km^2 and 1 graduate per 995 km^2 respectively, though the remaining surveying task in Africa, at the scales indicated, is six times larger in Africa than in Europe" (Reedman, and others 1996, p.15).

In 1995, the funding levels for GSOs from Africa were in general, on a per capita basis, the lowest for all regions covered in the BGS survey. At the same time, GDP per capita of these countries ranked among the lowest.

Another statistic that was particularly telling regarding the capacity of African GSOs was the number of professionally trained staff (i.e. graduate employees) in the office compared with other regions (see Table 5). Of all the regions covered by BGS, Africa, generally speaking, had the least number of professional staff, with a median of 22 per cent of all GSO staff; the Asia Pacific region had a median of 28 per cent and high income countries had a median of 51 per cent.

It was noted that staff retention in GSOs is difficult when salaries are low relative to those in the private sector (i.e. the mining sector), and that the budget for actual activities is very small because the majority of the budget is for staff salaries, leaving an insufficient amount left for mapping or other activities (Reedman, and others 1996).

Table 5: **Graduate employees as a percentage of total staff complement of 55 national geological survey organizations**

Geological survey organizations by income group and region	Graduate employees as a percentage of total staff complement	
	Range	Median value
High Income Countries	31–68	51
Low and Lower-Middle Income Countries — Africa and Middle East	3–35	22
Low and Lower-Middle Income Countries — South and Central America	5–54	37
Low and Lower-Middle Income Countries — Asia and Pacific	3–77	28

Source: Reedman, and others (1996).

More details regarding the results of the BGS survey of functions and their delivery by GSOs in the countries surveyed are available in annexes 2 (Figure 19) and 3 (Table 14) to the present document.

2.5.4 GSO capacity development

In addition to assessing GSO capacities, Reedman and others (1996) looked at technical assistance and strategies for improving the effectiveness and sustainability of such assistance to GSOs. Issues identified included a lack of alignment between what GSOs reported as priorities and the support being provided, and the risk of distracting and undermining efforts to address priority geological issues. Given that budgetary support runs the risk of creating dependency, a key question raised was whether geological support should only be given when it is sustainable or whether, in some instances, it is worth providing support even though it will not be sustainable, for example, when a specific information product such as a map would be produced.

Reedman and others (1996) found that the priorities of GSOs were mainly around undertaking and improving geological surveys and maps, including geological information systems. The focus of technical assistance provided by partners, however, tended to be on minerals, followed by surveying and mapping. It was noted that "…both GSOs and donors should be careful that technical assistance inputs into a particular core activity do not make such demands on the GSO's limited resources that the core programme is distorted and parallel activities are damaged" (Reedman, and others 1996, p.28). Accordingly, it is important for GSOs to accept the support that is offered and determine with technical partners the forms of technical support that will be the most effective in meeting GSO and national objectives.

Various forms of support can be offered and used by GSOs, including budgetary support, support for specific projects that might include budgetary and technical advice, or even support in the form of having another party undertake geological research on behalf of the country. Reedman and others (1996) suggested that a particularly effective form of support is having a long term professional linkage between two (and perhaps more) institutions where technical capacities are fostered.

In most cases, technical support will eventually cease or change, which raises the issue of sustainability of improvements in GSO capacities. Reedman and others (1996) pointed out that the World Bank as part of its mining strategy for Latin America and the Caribbean assessed countries in terms of GSO professional capacity and level of experience in mining (i.e. mining tradition) in order to gain a sense of the sustainability of suggested mining activities. It was noted by the World Bank that in some cases where the chances of sustainability are very low, a project may still be suitable to undertake if the project can bring clear and important benefits to a country.

2.6 Geoscience Australia's assessment of geoscience in Africa (2012)

The Australian Government through the Australian Agency for International Development (AusAID) established the Mining for Development Initiative to work with countries as a development partner, drawing from Australian expertise with the aim of helping countries use minerals to "...propel them on a path to inclusive and sustainable development" (Kay, and others 2012, p.1). As part of this initiative, AusAID commissioned a study to assess the mineral potential, geoscience service capacity, risk and geological aid in Africa, Asia, Latin America and the Pacific (see Kay, and others 2012).The study assessed 138 developing countries in terms of each country's geological survey capacity as well as their geological and mineral potential, socio-political risk and geological aid received. The report was based on public and commercial information collected by Geoscience Australia.

The assessment of GSO capacity was based on the information GSOs had on their websites. Geoscience Australia looked for data covering eleven categories: geology, geophysics, marine, hydrogeology, risk/hazard, remote sensing, mapping, mining, energy, publications and English language website availability (see Table 15 in annex 4 to the present document).

Each country had its geological survey rated using the following categories:

a) Strong capacity to collect and disseminate high quality geoscientific data and information;

b) Capacity to undertake major geoscientific surveys and disseminate data efficiently;

c) Some capacity to undertake major geoscientific surveys and to disseminate data;

d) Limited capacity to undertake geoscientific surveying; and

e) 0. No geological survey detected, or no information available.

It is important to note the GSOs that did not have English, French or Spanish content were assigned zeros, not necessarily because there was no content, but rather because the content was not accessible to a wide audience, according to Geoscience Australia. A drawback of this type of assessment is that it is based on the Internet. Thus, in many cases, GSOs will have far more information in hard copy format than in electronic format. Consequently, to get a true picture of the available information, a visit to the minerals office and library are usually required.

2.6.1 GSO capacity ratings

From its review of GSO websites, Geoscience Australia found that South Africa had a strong capacity to collect and disseminate high quality data and information. Egypt, Ethiopia, Morocco, Namibia and the United Republic of Tanzania were found to have the capacity to undertake major geoscientific surveys and disseminate data efficiently. Reflecting earlier studies, many country GSOs were found to either have some or limited capacity to undertake geoscientific surveys and then disseminate these data, and several countries were rated as having no GSO detected or no information available online (see Figure 1).

From the Geoscience Australia's country data it can be seen that 31 of the 34 country GSOs that were rated between one and four had geological information on their websites (see Table 15 in annex 4 to the present document). Notable exceptions were Comoros, Liberia and Mauritania, each of which were rated as having limited capacities to undertake geoscientific surveys. Table 6 shows that 29 GSOs had publications available while 22 had websites available in English. In terms of other technical areas, 23 GSOs had information on mapping, 23 had information on mining in their country, 17 had information on geophysics,16 had information on energy, 11 had information on hydrogeology, 9 had information on risk and hazards, 9 had information on remote sensing and 5 had information on marine geology. It should be noted that information on marine geology is not relevant for 16 African countries that are landlocked.

Table 6: Summary of key results from the country assessment

Area	Number of GSOs with information	Percentage of GSOs with information (i.e. rated 1-4 by Geoscience Australia)	Percentage of countries with information
Geology	31	91	58
Geophysics	17	50	32
Marine	5	15	9
Hydrogeology	11	32	21
Risk and hazards	9	26	17
Remote sensing	9	26	17
Mapping	23	68	43
Mining	23	68	43
Energy	16	47	30
Publication	29	85	55
Website in English	22	65	42

Source: Based on data from Kay, and others (2012).

For the continent as a whole, Table 6 shows that 58 per cent of countries had GSOs with accessible geological information and 43 per cent with accessible information on mapping. The report did not attempt to judge the quality of information.[3] These findings demonstrate that there are significant gaps in available data and information on Africa's geology and minerals potential.

It should be mentioned that the Geoscience Australia report included an assessment of minerals potential, the level of support (i.e. overseas development assistance) countries have had for their GSOs, and the perceived social and political risks associated with minerals investments in countries around the world. Many of these datasets are used later in this report.

3 Geoscience Australia covered a total of 138 countries in its study, including most African countries. The study was designed to provide guidance on where minerals related support should be directed and was not designed to be a definitive assessment of data quality.

Figure 1: Geoscience Australia's map presenting the results of its assessment of GSO capacities across Africa

Source: Kay and others (2012).
Note: The boundaries, the names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

2.7 EI Source Book assessment of geodata for development (2012)

The EI Source Book brochure from 2013 contains the following statement: "...activities can bring more costs than benefits to the country that hosts them." To remedy this, the organisation aims to address issues of minerals governance across several key areas: policy and law, contract and regulation, sector organisation and administration, fiscal design, revenue management, transparency and accountability, and sustainability, including broader impacts across the economy. The EI Source Book is supported by the World Bank, minerals industry associations and others.

The EI Source Book recently conducted an extractive industry sector survey, in which companies were asked about the types of geological information they required and the types of decisions data would be used for, along with company assessments of the quality and accessibility of geological information from GSOs across Africa. The EI Source Book survey, and resulting publication titled "Geodata for development: a practical approach", focused on geological information from the perspective of industry (i.e. exploration and mining companies, related consultancies and service providers).[4] It remains a useful tool for gaining a sense of industry thoughts on GSO and geological information related issues.

4 The survey did not cover artisanal and small-scale miners.

Table 7: **Overall rating of importance of information for minerals related investment decision making (from highest to lowest rank)**

Rank order (i.e. priority)	Type of geodata
1	Regional / country-wide processed airborne geophysical data (mag, radiometric, e-m) at ~400m line spacing or closer
2	Regional scale mineral occurrence maps
3	Geological maps in vector digital (suitable for a GIS) covering most or all the country at a scale of 1:200,000 or larger
4	Topographic data / maps
5	Supporting reports / memoirs / published papers
6	Geological maps (copies or scans of printed maps) covering most or all the country at a scale of 1:200,000 or larger
7	Cadastral maps / data
8	Mineral prospectivity summary brochures / booklets
9	Interpretations of airborne geophysical survey data
10	Regional scale metallogenic maps
11	Regional scale tectonic maps
12	Regional scale geochemical survey results at density of ~1 sample per 10 sq km
12	Interpreted satellite imagery
14	Hydrogeological maps
15	Geological maps (copies or scans of printed maps) covering most or all the country at a scale of 1:1million or smaller
16	Geological maps in vector digital (suitable for a GIS) covering most or all the country at a scale of 1:1million or smaller

Source: EI Source Book, 2012.

2.7.1 Industry survey results

The EI Source Book survey results show that, in general, African countries have poor quality or difficult to access geological data. However, Botswana and Namibia were highlighted as positive exceptions as the following quotes from the survey demonstrate (EI Source Book, 2012, p.6):

- "Namibia. An exception in African terms. Data easily accessible and cheaply available."
- "Botswana - open data policy. Working on getting more organized. Much available at no cost."

Survey results presented in the annexes of the Geodata for development report (2012), showed that a number of respondents found GSOs to have reasonable or good data, but unlike the Geoscience Australia report, assessments were not available for individual countries.

As part of the EI Source Book survey, respondents were asked about the types of information they needed most and how they would use this information. From the survey results, airborne geophysical data, maps of mineral occurrences and geology in electronic vector based geographic information system (GIS) formats were high priorities (see Table 7). For boardroom decisions on which prospects to take on, maps should be at scales of 1:500,000 or better and regional airborne geophysical data is sufficient. For mineral exploration purposes geological maps at scales of 1:200,000 are useful but scales of 1:100,000 are optimal (see Table 8). Airborne magnetic and radiometric data collected by flying lines 800 m apart are sufficient but lines flown 400m apart are most useful for exploration. For petroleum exploration, gravity data are preferred with similar line spacing.

Table 8: Information and applications

Type of information	Boardroom decision making	Exploration
Geothematic maps	Compilations of geological and metalogenic maps at 1:500 000 scale or smaller	Geological maps at 1:200 000 (minimal) / 1:100 000 (optimal)
Airborne geophysics	Regional picture	800 m (minimal) / 400 m (optimal) – magnetics and radiometrics
Geochemistry	-	Element contour maps based on 1 sample per 10 km2
Reports, papers and logs	-	Yes
Physical samples	-	Yes
Other	-	-

Source: Modified from EI Source Book, 2012.

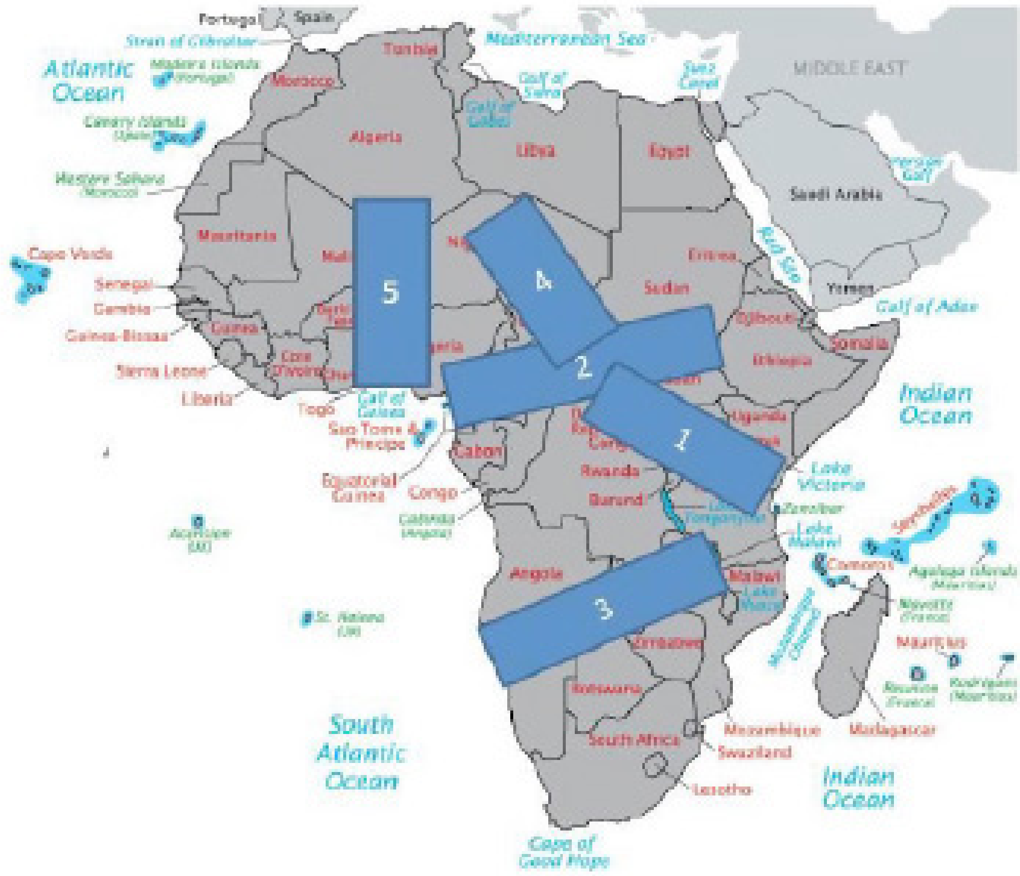
In addition to the findings above, there was a short discussion about motives of GSOs for limiting geological information. In some cases respondents to the survey indicated that either the GSO had sold data, which provided much needed income for the GSO, or that the GSO staff had sold information without receipts (i.e. cash only). Thus, vested interests, incentives and the need for well-financed African GSOs is something that may need to be addressed.

2.7.2 Zones for further exploration

The EI Source Book (2012) went beyond the survey and identified areas in Africa that might benefit most from more exploration, that is, areas that might have significant mineral potential based on publicly available geological information overlain with minerals and mines information. Based on this assessment, five zones were identified as being of high interest (see Figure 2):

- Zone 1 –United Republic of Tanzania (central and north), Kenya (south), Rwanda, Democratic Republic of the Congo (north-east), South Sudan (south and west) and Central African Republic (south-east);
- Zone 2 - Nigeria (south-east), Cameroon, Gabon (north), Central African Republic, South Sudan (north) and Sudan (south);
- Zone 3 - Namibia (north), Angola (south), Zambia, Zimbabwe (north) and Malawi;
- Zone 4 – Central African Republic, Chad and Niger (east);
- Zone 5 - Ghana (east), Benin, Nigeria (west), Burkina Faso and Mali (east).

Figure 2: Five zones identified as being priorities for having more geological information



Source: ElSourceBook 2012
Note: The boundaries, the names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

2.7.3 Proposed activities for improving information for mining companies

Based on the survey and other information, a sequence of four activities or "stages" were stipulated in the EI Source Book report (2012) that could be conducted to improve geological data for mining companies:

a) Compile existing geological maps and reports, and reprocess existing airborne geophysics with the synthesis information presented in resource prospectivity reports, booklets and brochures;

b) Digitize and reinterpret Colonial era maps, including maps held by countries outside of Africa (including limited ground-truthing based on field mapping of key locations to ensure reinterpretations match reality);

c) Acquire high-resolution airborne magnetic and radiometric data for minerals and gravity for petroleum (depending on the interest and finance available this could be done for a country, zone or for a smaller set of target areas);

d) Develop high-resolution geological maps drawing from information in steps two and three above and other research.

2.7.4 Proposed institutional arrangements

Various institutional arrangements were proposed in the EI Source Book report (2012) that could help ensure data are available for mining companies, such as having minerals data held in the "cloud" by a commercially operated entity outside of Africa, which would ensure data access and high bandwidth for the transmission of data. Among the proposals, it was suggested that GSOs be compensated for sharing their data on minerals. It was noted that there had been many development assistance projects related to geological information, and that those projects might lead to limited short term improvements but lower than desired levels of long term improvements in information provision. Consequently, it was suggested that future development assistance should have clauses that specify that data and information should be shared publicly.

Finally, the impact good geological data might have on attracting investment was investigated and it was found that good geological data helps attract investment to a country when the minerals industry is looking for investment opportunities. However, if the minerals industry is going through a bust phase or prices are low, then information alone is not sufficient to attract further investment. It was also noted that good geological information may help mitigate fears and perceptions regarding the security of investing in African countries.

2.8 Zambian case study (2013)

The International Mining for Development Centre (IM4DC) undertook an action research project regarding geology and mineral information systems and processes in Zambia. The project identified gaps and challenges and proposed steps for increasing GSO and other capacities in Zambia to collect, compile and use geological information (Scott, 2013). The study involved interviewing senior staff from geology and minerals related institutions, mining companies and international institutions. The interviews covered several diverse issues:

- Institutional arrangements;
- Geological information needs of various organisations;
- Data and information processes (e.g. related to data acquisition);
- The interpretation and dissemination of data and information;
- The relationship between geological information, development and planning;
- Geological information systems related capacity-building measures that can be engaged in.

From the interviews, institutional arrangements and responsibilities were presented, challenges were highlighted and concrete proposals were made for increasing GSO and other capacities in Zambia.

At the time of the survey, the responsibilities of the Geological Survey of Zambia (GSZ) included: field mapping and initial exploration activities, minerals permit processing and licensing, as well as serving as a repository for geological, geophysical and geochemical data, reports, maps and other information. According to its overarching Strategic Plan, the GSZ was committed to:5

- Increasing geological mapping coverage of the country from 58 percent to 61 percent by 2012;
- Having the core shed built and fully functional by 2012;
- Developing capacity in information management, for example:
    - Establishing and maintaining an integrated information system to enhance the processing, storage, retrieval and accessibility of comprehensive geological, petroleum and mining information;
    - Identifying, documenting, packaging and disseminating information on investment opportunities in the mining and petroleum sectors locally and abroad; and

5 List modified from Scott (2013, p.9).

- Streamlining the processing of mining rights and other related documents, such as exploration reports, among others).

A key challenge for GSZ was to improve information management practices. This included digitising historical reports, maps and other information, applying standards and templates for the submission of electronic data by mining companies, and ensuring standards allow the meaningful integration of GSZ and other mining data and information. Confidentiality and the management of confidential data were other issues identified. Finally, there were challenges identified when it comes to accessing data and maintaining datasets. Other issues and opportunities identified by the project included minerals legislation and regulation, and the engagement of tertiary institutions, such as the University of Zambia.

To address the geology and minerals challenges identified, Scott (2013) proposed a set of training activities that focus on:

- Data format and integrity;
- Technology assessment;
- The mining sector and geoscience in government planning.

2.9 Spatial data infrastructure and related issues

Geographic Information Systems (GIS) are increasingly being used to organize geological data and associated information in electronic formats. Maps have been used to represent geological information since the advent of geology as a science. It is important, therefore, to examine issues of GSO capacity in the wider context of GIS and spatial data infrastructure. The following sections address fundamental geographic datasets for Africa as well as issues and progress in the area of establishing spatial data infrastructure in African countries.

2.9.1 Fundamental datasets for Africa (2007)

In 2007, a study was conducted entitled "Determination of Fundamental Datasets for Africa: Geoinformation in Socio-Economic Development"6 (ECA, 2007). Fundamental datasets were defined as the "...minimum primary sets of data that cannot be derived from other data sets, and that are required to spatially represent phenomena, objects, or themes important for the realisation of economic, social, and environmental benefits consistently across Africa at the local, national, sub-regional and regional levels."

The study identified the following datasets as being fundamental based on a user needs assessment, a desktop study, a survey and interviews:

a) Geodetic control network
b) Imagery (from remote sensing)
c) Hypsography
d) Hydrography
e) Boundaries
f) Geographic names
g) Land management units/areas
h) Transportation
i) Utilities and services
j) Natural environment (consisting of land cover, soils and geology)

Spatial information on the natural environment (including geological information) was included in the list of fundamental datasets. However, at the subregional level, not every subregion in Africa considered geological information as being fundamental (see ECA, 2007; annex 5 to the present document) West Africa found minerals of relatively low importance and East Africa did not rate geological information or minerals data as being fundamental. Southern Africa found geological data to be a relatively high priority, while North Africa found geological information to be moderately important (see ECA, 2007; annex 5 to the present document).

6 The study was prepared by The Human Sciences Research Council and EIS Africa for the Working Group on Fundamental Data Sets of the Sub Committee on Geoinformation of the Committee on Development Information, Science and Technology of the Economic Commission for Africa. The study was funded by the Chief Directorate of Surveys and Mapping, Department of Land Affairs in South Africa.

It is important to note that water related information was rated as being very important by all organisations and groups surveyed as part of the study (e.g. Table 16 and Table 17 to the present document). In many cases, GSOs hold significant hydrographic and hydrological data. Consequently, GSOs are an essential part of national spatial data infrastructure (NSDI), both for hydrological and geological information.

The study also set out the spatial features and related attribute information that make up geological and natural water body datasets (see ECA 2007; Table 9 to the present document). The attributes are fairly basic compared with the information that GSOs could be expected to hold as they reflect attributes for spatial data infrastructure (SDI) and integrated planning rather than geological or mineral related purposes.

Table 9: Spatial features and attributes related to natural water bodies and geology identified as being fundamental for Africa

Datasets	Spatial features	Attributes
Natural water bodies	Streams and rivers (perennial, intermittent/seasonal), canals, ponds, lakes, wetlands, wells	Unique code, name, length, surface area
Geology	Lithological units/contacts	Unique code, name, age, stratigraphy
	Structure	Unique code, name, type, age
	Regional boundary (geological)	Major rock formation and sequences
	Regional structure features	Type of feature (e.g. faults, joint)
	Major ore deposit	Type, name, commodity

Source: Modified from ECA (2007).

2.9.2 Spatial data infrastructure in Africa (summary)

Although there are many possible definitions, SDI can be defined as: "a coordinated series of agreements on technology standards, institutional arrangements, and policies that enable the discovery and use of geospatial information by users and for purposes other than those it was created for" (Khune, 2005). SDI and National Spatial Data Infrastructure (NSDI) facilitate the wider integration and analysis of geological information with social, economic and other environmental data, which maximizes the development benefits of information managed and disseminated by GSOs. Without adequate NSDIs, the wider development benefits that may come from GSO information are unlikely to be realised.

2.9.2.1 Implementation

Crompvoets and others (2004) showed that 67 countries had implemented SDIs globally, including 10 countries in Africa. The ability of geological data to be integrated with other data for wider development benefits depends, in large part, on the level of progress in African countries implementing NSDI.

2.9.2.2 Progress and challenges

After the inception of SDI in Africa, the following recommendation was made at the second Committee on Development Information Conference in 2001: "SDI should be made an integral part of the national information and communications policies, strategies and plans, and should take into account the cultural and socio-economic situations in each country" (Yilma, 2013). Over a decade later, in an ECA paper for the Global Geospatial Conference 2013, which was held in Addis Ababa, Ethiopia, Aster Denekew Yilma highlighted progress and challenges in implementing NSDI in Africa and found that progress included the formation of bodies in Africa to promote NSDIs and harmonise standards (Yilma, 2013). Guidance documents regarding geographic data standards to be used in Africa had been developed (e.g.

African Metadata Profile) and others were under development, such as the African Geodetic Reference Frame. At least five countries had made progress on legal components required to facilitate NSDIs consisting of Kenya, Nigeria, Rwanda and South Africa and Uganda (Yilma, 2013). Furthermore, Yilma (2013) noted that in Rwanda and Uganda there is high level political support driving the implementation of NSDIs.

However, the following challenges remain:

- A lack of geographic data coverage
- A lack of recent data;
- A lack of information to help users find existing geographic data;
- A lack of data sharing mechanisms;
- A lack of clarity on roles and responsibilities;
- Poor coordination between organisations;
- Limited funding available to support many NSDI initiatives and the institutions involved;
- A lack of interoperability of data among institutions;
- Too much geographic information remains in hard copy (i.e. paper based) and have not been scanned or digitised into vector formats.

2.9.2.3 SDI readiness

Delgado and others (2005) examined factors of SDI readiness (see Table 10) and noted that NSDIs in some countries replicated initiatives in other countries but lacked inherent sustainability because some NSDIs were not appropriate to specific national circumstances or capacities. While the SDI readiness index measures do not appear to have been applied in Africa, the factors and criteria provide a checklist when looking at the viability of SDI initiatives in Africa, and they complement the list of challenges identified by Yilma (2013).

Table 10: Factors of SDI readiness

Factor	Criteria
Organizational	Politician vision
	Institutional leadership
	Umbrella legal agreement(s)
Information/ data availability	Digital cartography availability
	Metadata availability
People	Human capital
	SDI culture-education
	Individual leadership
Access network	Web connectivity
	Telecommunication infrastructure
	Geospatial software availability / own development / open source
Financial resources	Government central funding
	Data policy aimed to return on investment
	Private sector activity

Source: Delgado, and others (2005).

Many NSDIs in Africa are supported at least in part through donor funds. Lance and others (2005) tracked geospatial investments in Africa and found that some funds detracted from coordination between geospatial datasets and the effective establishment of SDIs, leading to fragmentation. Many investments went to single institutions for specific data applications. Better budgetary processes were found to be needed, including: the involvement of SDI programme managers, the avoidance of duplicate investments, and the need to ensure that investments follow SDI priorities and have cross-institutional support.

The challenges of integrating geological data with other data to meaningfully inform broader development issues seem formidable based on the research to date. However, the opportunity to better coordinate and harmonise data with the resulting analytical benefits suggests that efforts in SDIs will continue, albeit with varying levels of success. Given this situation, the question remains as to how geological data can be integrated towards information specific development issues and options.

3 Gap analysis

The gap analysis in the present study assesses the need for information on minerals and mining, energy, hydrogeology and geological hazards with the capacity of African GSOs to provide information in these areas. Gaps exist where there is a high need relative to the amount of information available on minerals and mining, energy, hydrogeology or geological hazards.

3.1 Overarching methodology

For minerals and mining, energy, hydrogeology and geological hazards, indicators for the level of information needed have been identified using data from international data sources. These indicators are compared with indicators regarding GSO capacities in each of these areas drawing from data published by Geoscience Australia (see Table 15 in annex 4 to the present document).

For minerals and mining, energy, hydrogeology and geological hazards, the indicators and data used are discussed in the sections below along with the results of the gap analysis. It should be noted that needs assessments are imperfect and the results are indicative, providing a sense of where the gaps are and the size of these gaps.

3.2 Minerals and mining

3.2.1 Indicators

Indicators of need for mineral and mining consisted of mining and quarrying as a proportion of GDP (UNData, 2013) and the geological potential for minerals (Kay, and others 2012). The indicator of GSO capacity was based on the Geoscience Australia assessment discussed in section 2.4 above.

3.2.1.1 Mining and quarrying as a percentage of GDP

Data for calculating mining and quarrying as a proportion of GDP came from the United Nations Statistics Division National Accounts (2013) accessed via UNData. The data used the International Standard Industrial Classification of All Economic Activities Revision 3 (ISIC Rev.3) (United Nations Statistics Division, 2002) and the System of National Account 1993 (United Nations Statistical Commission Inter-Secretariat Working Group on National Accounts, 1993). Because the indicator consists of a ratio, there was no need to adjust for inflation or to use a common currency. However, under ISIC Rev.3 “mining and quarrying” includes not only mining and quarrying but also the extraction of crude petroleum and natural gas and related service activities (see Table 11). As such, the indicator is not restricted to minerals information needs alone.

Table 11: Economic activities included under mining and quarrying

C - Mining and quarrying
10 - Mining of coal and lignite; extraction of peat
11 - Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction excluding surveying
12 - Mining of uranium and thorium ores
13 - Mining of metal ores
14 - Other mining and quarrying

Source: United Nations Statistics Division, 2002.

Figure 3: Geoscience Australia's assessment of the minerals potential of African countries

Source: Kay, and others (2012).

Note: The boundaries, the names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Mining, quarrying and petroleum as a percentage of GDP values were plotted and compared with assigned values for the capacity of the GSOs (see Figure 4).GSOs with no information were assigned 0, those rated as having limited capacities were assigned 0.1, those rated as having some capacity were assigned 0.2, those rated as having capacity were assigned 0.3 and those rated as having strong capacities were assigned 0.4. Countries with higher proportions of their GDP coming from the economic activities of mining, quarrying and petroleum (i.e. those at the top of the graph) were considered to have a higher need for good information on minerals and mining coming from GSOs.

3.2.1.2 Geological potential

The geological potential, as assessed by Geoscience Australia, consisted of three categories:

- Proven substantial resources and production of mineral commodities;
- Potential with some known resources or production of mineral commodities;
- No data or limited data of uncertain quality.

Values were assigned as follows: 0 = no data (unknown); 0.25 = potential; 0.5 = proven and substantial resources. For many countries around the world there was a lack of information upon which to make reasonable assessments, especially for smaller countries (Kay and others 2012, p.7).

The minerals potential of countries and GSO capacities are presented in Figure 5. Countries with the greatest geological potential for mining were assumed to have a higher need for good information coming from GSOs; they appear at the top of the graph. However, an important caveat is that geological knowledge, and assumed minerals potentials, can change significantly upon the collection of more geological information.

3.2.2 Results

There are 22 African countries for which mining, quarrying and petroleum account for over 5 per cent of their GDP (Libya to Niger in Figure 4). Of these countries, only three (Egypt, Namibia and South Africa) are rated by Geoscience Australia as having GSOs with either strong capacity or capacity to undertake surveys and disseminate data. All other countries are rated as having either some capacity to undertake geological surveys and disseminate data (seven countries), limited capacity to undertake geological surveys (four countries) or no capacity or information was available or detected (seven countries). In nearly half of African economies mining, quarrying and petroleum are significant contributors to GDP (i.e. greater than 5 per cent of GDP), but in most of these countries there is little if any available information to support either the growth of the industry or negotiations between governments, communities and miners, both domestic (including artisanal) and foreign.

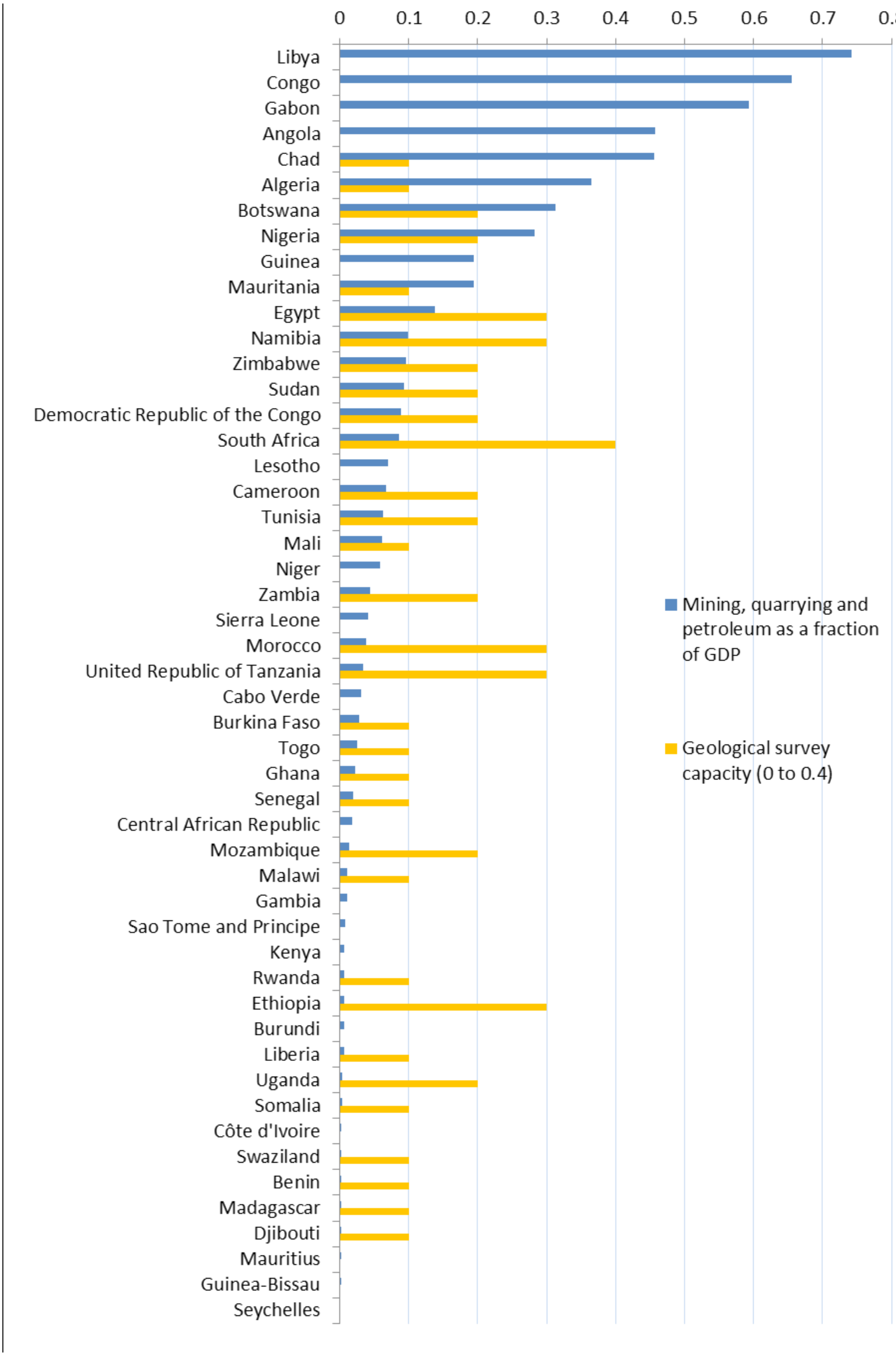
Petroleum based economies dominate the top of the graph (see Figure 4) with Libya having the greatest proportion of its economy based on mining, quarrying and petroleum (at 74 per cent in 2007). The Congo and Gabon also have over 50 per cent of their economies based on mining, quarrying and petroleum, at 66 per cent and 59 per cent respectively. Geoscience Australia found that Angola, the Congo and Libya did not have publically available information related to minerals or energy. It is possible that in some of these countries there is significant geological information but it may be restricted.

Other countries with less than 5 per cent of GDP due to mining, quarrying and petroleum had fairly significant operations, such as Zambia and Sierra Leone where mining, quarrying and petroleum contributed 4.3 per cent and 4.1 per cent to their economies respectively (see Figure 4).

In some countries, mining, quarrying and petroleum activities may have been limited even though there is geological potential for economic mineral occurrences the development of an industry at artisanal and industrial levels. This was taken into account by a second indicator (geological potential for minerals, see Figure 5) which was used to indicate levels of minerals information needed.

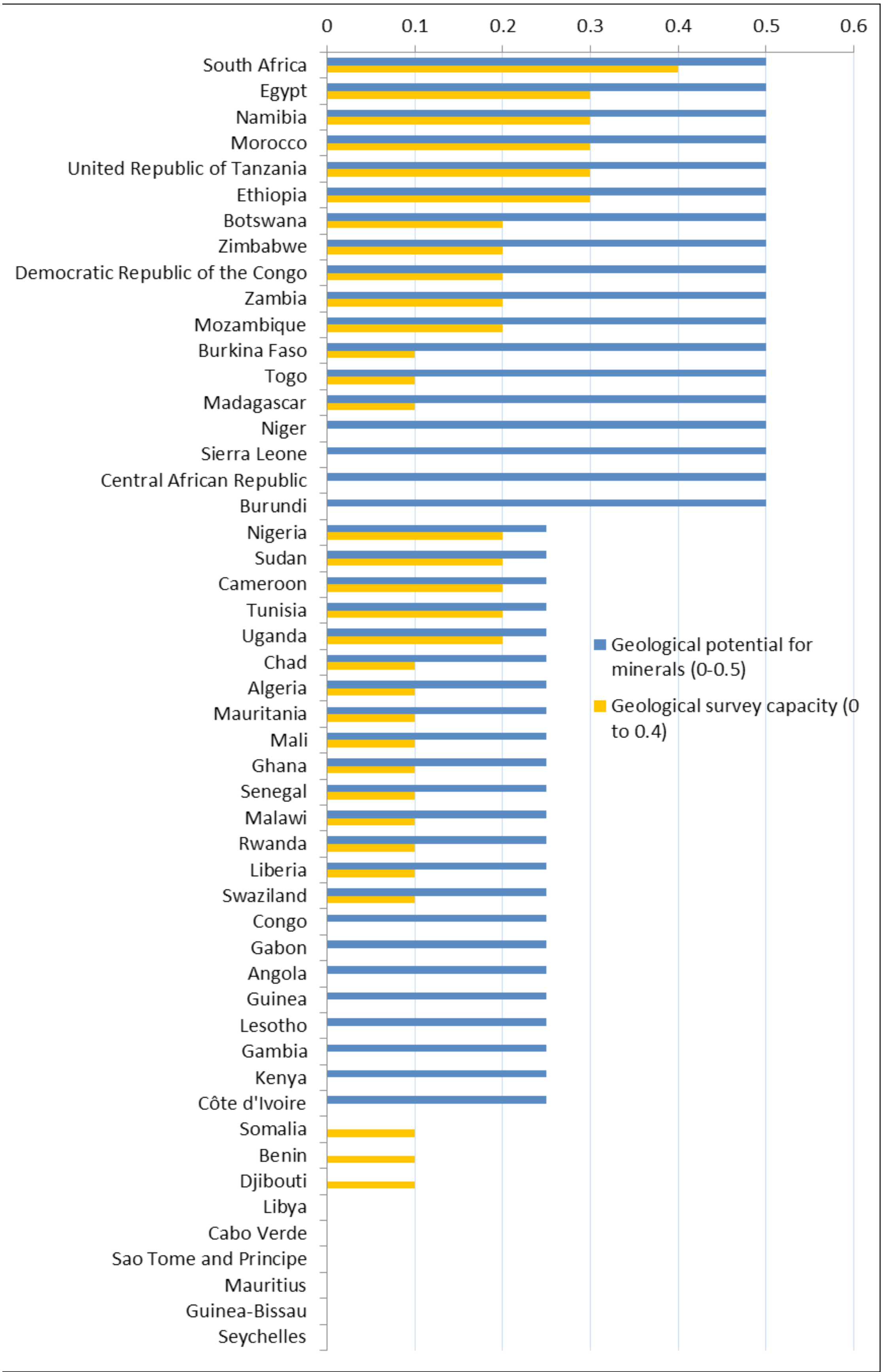
For the 18 African countries rated by Geoscience Australia as having “proven substantial resources and production of mineral commodities”, six had the capacity to conduct geological surveys and disseminate data, consisting of: Egypt, Ethiopia, Morocco, Namibia, South Africa (strong capacity) and the United Republic of Tanzania. Of the other countries with proven substantial resources, four were rated as either having no information or information was not detected, consisting of: Burundi, Central African Republic, Niger and Sierra Leone. Finally, three countries were assessed as having limited capacity to undertake surveys and five were rated as having some capacity to undertake surveys and disseminate data (see Figure 5).

Figure 4: Mining, quarrying and petroleum as a proportion of GDP relative to the geological survey capacities



Source: UNSD (2013), Kay and others (2012).

Figure 5: Geological potential for mineral resources relative to geological survey capacity



Source: Kay and others (2012)

Twenty three African countries were rated by Geoscience Australia, as having "potential with some known resources or production of mineral commodities". Of these, none were rated as having the capacity to undertake geological surveys and disseminate data. Five countries were rated as having some capacity to undertake surveys and disseminate data. Ten countries were assessed as having limited capacity to undertake surveys. Eight countries were rated as either having no survey data or data could not be detected.

Another 9 countries were rated as having no data or limited data of uncertain quality, and only three of these were rated as having limited geological survey potential. The remaining six countries either had no survey capacity or no data was detected (see Figure 5).

For more information on the indicators used to assess minerals information needs and gaps, see annex 6 to the present document.

3.3 Energy

3.3.1 Indicators

In the Geoscience Australia assessment, information on energy was defined as being information about the "generation of petroleum and geothermal specific products" including, for example, oil seeps and other petroleum signatures maps, and maps for geothermal energy and temperature at depth maps. Another type of energy for which geological information is essential is hydro-electricity. GSOs that collect general hydrological information might have information useful for hydro-electricity in terms of generation potential. However, geotechnical and hazards related data are also essential for assessing the technical feasibility of hydro dams and their reservoirs. The Geoscience Australia assessment did not address hydro-electricity potential in the energy category, but hydro-electricity is addressed in the energy category of this gap analysis.

For the energy gap analysis, indicators of the importance of having information on petroleum, geothermal energy and hydro-electricity were created. For petroleum, which includes crude oil and natural gas, the indicator was proven reserves found in African countries. This included data from OPEC (2012) on proven crude oil reserves and data from British Petroleum (2013) on proven natural gas reserves. For geothermal energy the indicator was existing production or potential as indicated by previous geothermal exploration activities (Teklemariam, 2010). For hydro-electricity the indicator consisted of the installed capacity added to the potential additional capacity. For petroleum, geothermal and hydro an indicator on the information potentially available from a GSO was created, based on processing of Geoscience Australia's data on GSO capacities (see annex 7 to the present document).

For petroleum the indicator of information potentially being available was whether or not Geoscience Australia found energy information available from a GSO. For geothermal energy the possible availability of information was assessed based on whether Geoscience Australia found that there was energy and hydrological information available. For hydro-electricity the assessment was based on whether Geoscience Australia found information available on geology, hazards, hydrology and mapping (see annex 7 to the present document).

The Geoscience Australia assessment on energy is a bit difficult to use because it did not specify whether there was information related to petroleum and/or geothermal energy. The assessment did not cover coal or other geological sources of energy (e.g. uranium) due to a lack of information.

3.3.2 Results

In Africa there are a range of potential energy resources, including petroleum, geothermal energy and hydro-electricity. GSOs have a role in storing and sharing data and other information that can support the development and utilisation of these resources, e.g. seismic data for petroleum, geothermal information for geothermal electricity and direct use projects, and geotechnical information, maps, and possibly hydrological information for hydro-electricity and reservoir related projects.

3.3.2.1 Petroleum

Table 12: GSO capacities, petroleum reserves and the availability of energy information in African countries

Country	GSO capacity rating*	Crude oil reserves (million barrels)**	Natural gas reserves (million barrels of oil equivalent) ***	Total petroleum reserves (million barrels of oil equivalent)	Energy information available from GSO^
Nigeria	3	37,139	34,320	71,459	Y
Libya	0	48,472	9,900	58,372	N
Algeria	4	12,200	29,700	41,900	N
Egypt	2	4,400	13,200	17,600	Y
Angola	0	9,055		9,055	N
Sudan	3	6,700		6,700	N
Gabon	0	2,000		2,000	N
South Africa	1				Y
Morocco	2				Y
Cameroon	3				Y
Equatorial Guinea	3				Y
Democratic Republic of Congo	3				N
Tunisia	3				N
Chad	4				Y
Ghana	4				Y
Mauritania	4				N
Rwanda	4				N
Côte d'Ivoire	0				N
Republic of the Congo	0				N
South Africa - Congo		10,105	8,580	18,685	

* Source: Geoscience Australia (Kay, and others 2012).
** Source: OPEC, 2012.
*** Source: BP, 2013.
^ Reprocessed information from Geoscience Australia (Kay, and others 2012).

There is significant interest in petroleum in Africa, especially as large resources are found in new places (e.g. in Kenya, Mozambique, Uganda and the United Republic of Tanzania). However, available data on reserves are out of date and do not provide a full picture of Africa's petroleum potential. As of 2012, 19 African countries had existing petroleum industries, according to Geoscience Australia (see Figure 6), and of these Nigeria had the largest proven reserves with 37 billion barrels of crude oil and 34 billion barrels of oil equivalent energy in natural gas reserves. Of the 19 African countries with petroleum, only seven of their GSOs were found to have information on energy available. Of the African countries with large petroleum reserves, only Egypt had available energy information and was rated by Geoscience Australia as having the capacity to undertake geological surveys and disseminate information. Nigeria was assessed as having some capacity, as was Sudan,[7] although only Nigeria had energy data available. Geoscience Australia could not detect

7 The Geoscience Australia assessment took place as South Sudan was formally gaining its own independence from the rest of Sudan. Consequently, the assessment reflects capacities in the former Sudan.

Figure 6: African countries with existing petroleum industries

Source: Kay, and others (2012).

Note: The boundaries, the names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

information on energy for Angola, Gabon and Libya.

Of the countries with smaller petroleum industries, South Africa was rated as having strong GSO capacity, while Morocco was assessed as generally having capacity. Both of these countries had energy data available. Other countries that had energy data available were Cameroon, Chad, Equatorial Guinea, and Ghana. The remaining countries did not have available energy data, according to Geoscience Australia (see Table 12).

3.3.2.2 Geothermal

Wherever there is groundwater coupled with volcanic systems, or high geothermal gradients for other reasons, there is geothermal energy potential. For geothermal energy most of the potential in Africa is concentrated along the Rift Valley. There have been some general assessments of geothermal potential in African countries (Teklemariam, 2010). Geothermal potential has been used as an indicator of the need for geothermal information by African countries. Table 13 shows countries along the Rift Valley that have been identified as having geothermal energy potential (Teklemariam, 2010) and compares this with the availability of information on energy and hydrology as assessed by Geoscience Australia (Kay, and others 2012).

Of the 13 countries identified as having geothermal potential in Table 13, only two are producing geothermal energy, specifically Ethiopia and Kenya with 7 MW and 209 MW of installed capacity respectively (Teklemariam, 2010). Both Ethiopia and Kenya have initiatives to increase geothermal installed capacity, but

Table 13: Geothermal production and potential of countries relative to the availability of information that might be useful for geothermal energy assessments

Countries	Potential / Production*	Energy **	Hydrology **	Geothermal related information availability (0-2)^
Ethiopia	Production	Y	Y	2
Kenya^^	Production	N	N	0
United Republic of Tanzania	Potential	Y	Y	2
Democratic Republic of the Congo	Potential	N	Y	1
Mozambique	Potential	N	Y	1
Burundi	Potential	N	N	0
Comoros	Potential	N	N	0
Djibouti^^	Potential	N	N	0
Eritrea	Potential	N	N	0
Malawi	Potential	N	N	0
Rwanda	Potential	N	N	0
Uganda	Potential	N	N	0
Zambia	Potential	N	N	0

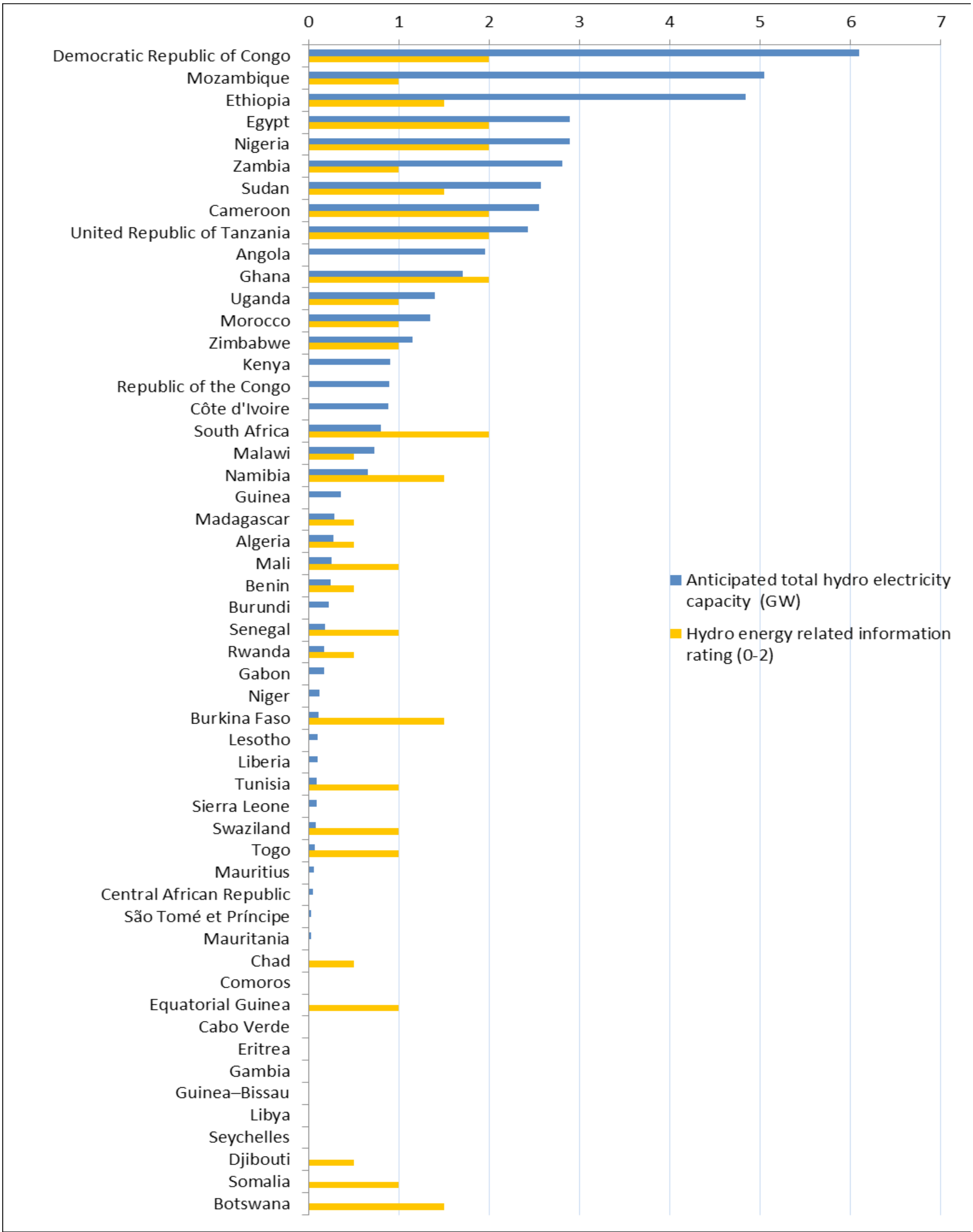
* Source: Adapted from Teklemariam (2010).
** Source: Geoscience Australia (Kay, and others 2012).
^ Processed data from Geoscience Australia (Kay, and others 2012).
^^Kenya and Djibouti have other offices (other than the GSO) that address geothermal energy.

only Ethiopia had energy and hydrological information available according to Geoscience Australia. Of the other 11 countries with geothermal potential, one (the United Republic of Tanzania) had information on both energy and hydrology, and two (Democratic Republic of the Congo and Mozambique) had information only on hydrology. The remaining countries lacked data on energy and hydrology from GSOs. It should be noted that in some cases other government offices keep information on geothermal energy outside of GSOs.

3.3.2.3 Hydro-electricity

Figure 7 shows that the countries with the greatest hydro-electricity potential tend to have better availability of information that might be useful for such projects. Countries were rated from zero (no information) to two (maximum amount of information). Fourteen African countries either had installed capacities or the potential for a total installed hydro-electric capacity of greater than 1 GW (i.e. 1000 MW), ranging from the Democratic Republic of the Congo (6.1 GW) to Zimbabwe (1.2 GW) (see Hydropower and Dams, World Atlas, 2009). Of these 14 countries, six had information on geology, hazards, hydrology and mapping. Two countries had information on three of these four areas, while five countries had information on two of the four areas. Geoscience Australia only found one country without any apparent information available on geology, hazards, hydrology and mapping. For countries with less than 1 GW total potential hydro-electricity capacity, the number of areas covered in terms of geology, hazards, hydrology and mapping tended to be less than for those countries with over 1 GW.

Figure 7: Anticipated total hydro-electricity capacity relative to the availability of information that might be useful for hydro-electricity projects



Source: Hydropower and Dams, World Atlas (2009), Kay and others (2012).

3.4 Hydrogeology

3.4.1 Indicators

The gap analysis examined water data from FAO AQUASTAT (2013) and compared it to what Geoscience Australia had found on the availability of hydrogeological information. The Geoscience Australia assessment defined hydrogeological capacity as being: "Groundwater and surface hydrogeological systems assessment capability" (Kay, and others, 2012, p.115).

For hydrogeology, two approaches and three indicators were used to assess the need for hydrogeological information. The first approach asked how much of the country's renewable water is in the form of groundwater? The question was based on the assumption that the greater the proportion of groundwater, the greater the need for hydrogeological information. The second approach entailed two questions:

a) How much water is being used relative to the amount of water available?

b) How much renewable water is there on a per capita basis?

The last two questions were based on the assumption that those countries using the greatest amount of their renewable water resources, or with the least overall renewable water resources per capita, would need more water and hydrogeological information.

The indicator of hydrogeological capacity was based on an analysis of the Geoscience Australia data (see annex 8 to the present document). The indicator had five components: geology, geophysics, hydrogeology, remote sensing and mapping. The most important component was whether hydrogeological information was available, which was weighted at 0.6. Each of the other components that may be useful in terms of hydrogeological studies were weighted at 0.1. Thus, for each country the indicator of GSO hydrogeological capacity was rated between 0 and 1. The ratings were indicative because they did not take into account the quality or quantity of information available. The indicator of GSO hydrogeological capacity in Figure 8 was rescaled from 0 to 1 to 0 to 0.5 for the sake of presentation.

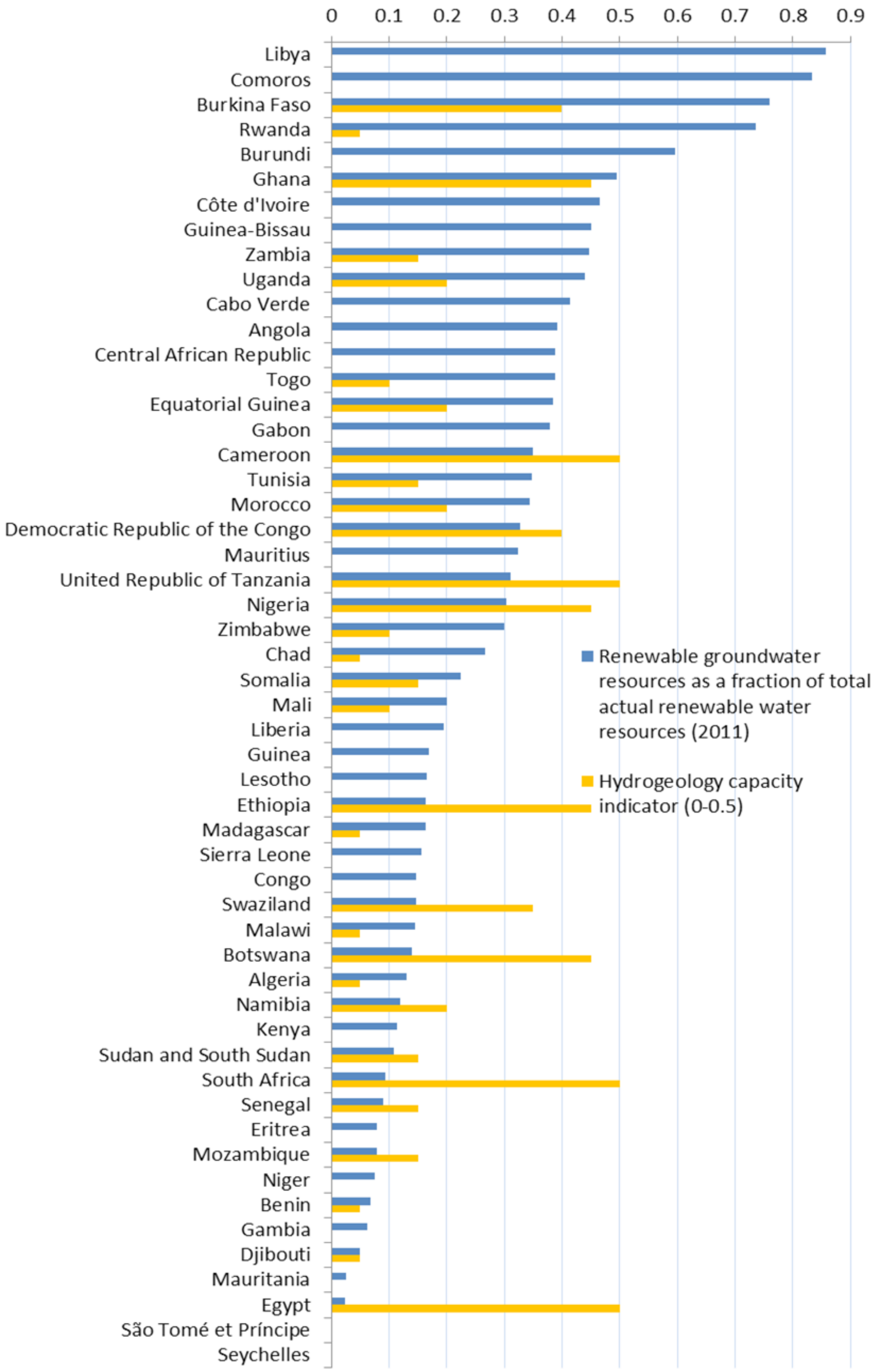
3.4.2 Results

In 25 African countries renewable groundwater resources constituted greater than 25 per cent of their total renewable water resources (see Figure 8), and of these, five countries—Burkina Faso (76%), Burundi (60%), Comoros (83%), Libya (86%) and Rwanda (74%) — had over 50 per cent of their renewable water resources as groundwater (see FAO AQUASTAT, 2013). Only Burkina Faso's GSO had information directly regarding hydrogeology, according to the Geoscience Australia assessment (see Kay, and others 2012). Rwanda had other information that may or may not have been useful for the purposes of hydrogeological studies.

With regards to total renewable water, there was overlap between groundwater and surface water because water moves between surface water and groundwater systems. The indicator did not take into account fossil groundwater (with a limited lifespan as a resource) that can be extracted. Fossil water is especially important to Libya, which abstracts 615 per cent of its total renewable water resources. Libya is dry but it does have large, primarily fossil groundwater aquifers, which enable it to use more water than it receives through recharge in a year. Consequently, Libya's aquifers are being drawn down. Geoscience Australia's assessment did not detect any information on hydrogeology as no English, Spanish or French website was available for Libya at the time of publication.

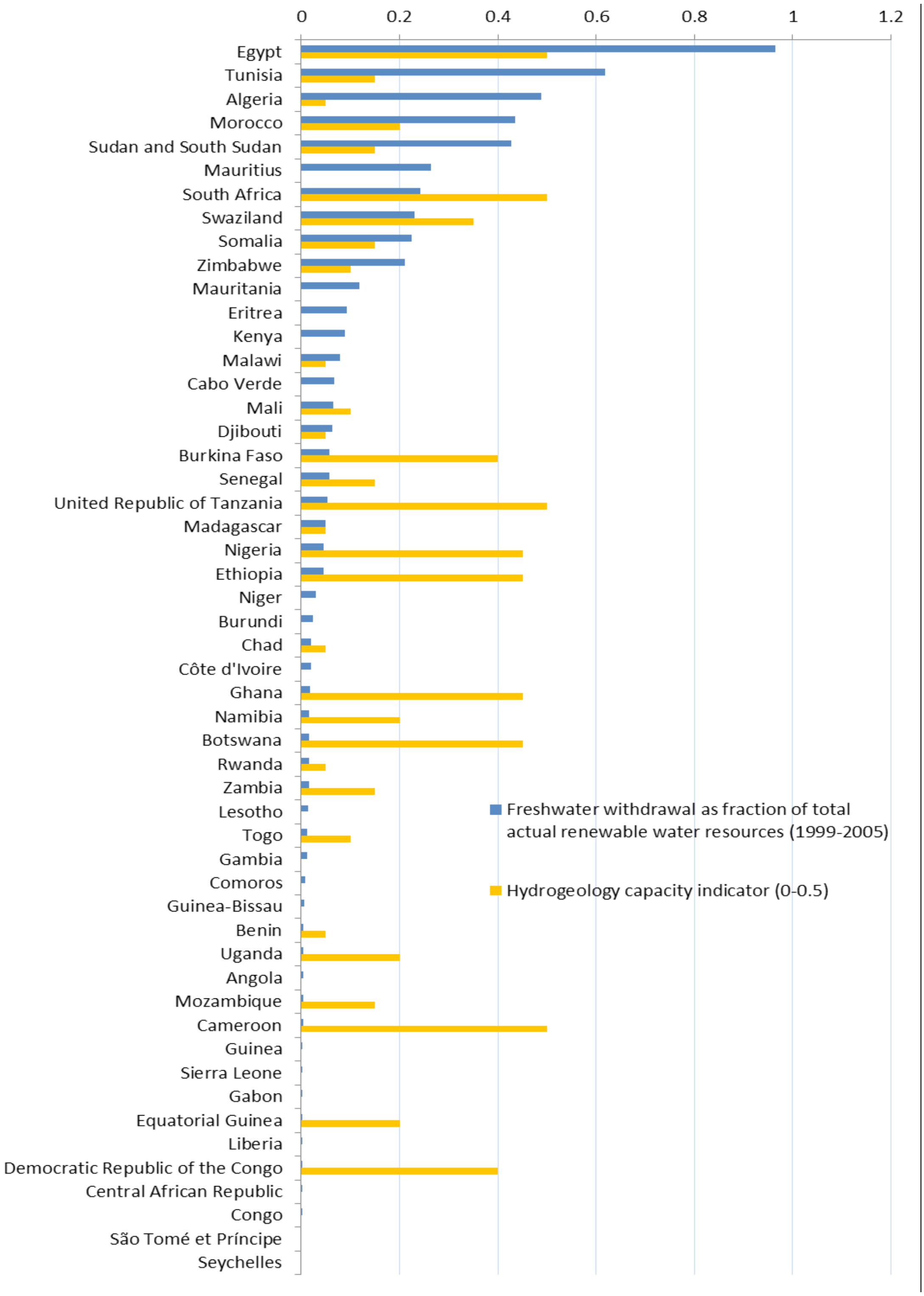
Figure 9 (based on data from FAO AQUASTAT, 2013) reveals that 11 African countries were using more than 20 per cent of their renewable water resources: Libya (615%), Egypt (97%), Tunisia (62%), Algeria (49%), Morocco (44%), the former Sudan (43%), Mauritius (26%), South Africa (24%), Swaziland (23%), Somalia (22%), and Zimbabwe (21%) (see Table 20 in annex 8 of this document). Of these, only three had hydrogeological information available, and of the remaining eight, six had other information that might be useful for hydrogeological research.

Figure 8: Graph of renewable groundwater resources as a percentage of total renewable water resources and the indicator of GSO hydrogeological capacity



Source: FAO AQUASTAT (2013), Kay and others (2012).

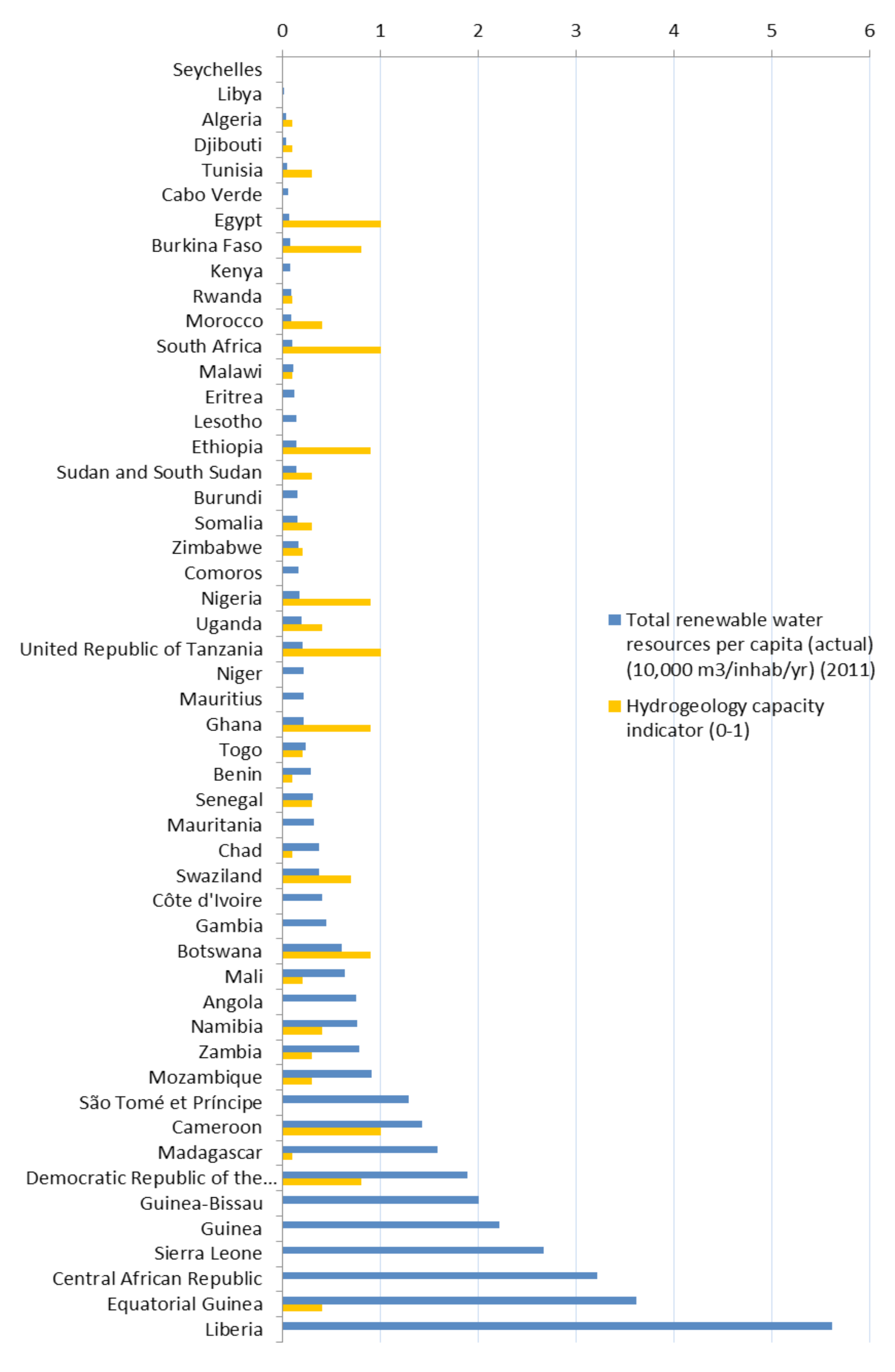
Figure 9: Graph of freshwater withdrawals as a percentage of total renewable water resources and the indicator of GSO hydrogeological capacity



Source: FAO AQUASTAT (2013), Kay and others (2012).

Ten African countries were abstracting between 5 per cent and 20 per cent of their renewable water resources, consisting of: Mauritania (12%), Eritrea (9.2%), Kenya (8.9%), Malawi (7.9%), Cabo Verde (6.8%), Mali (6.5%), Djibouti (6.3%), Burkina Faso (5.7%), Senegal (5.7%) and the United Republic of Tanzania (5.4%) (see Figure 9). Of these countries, only two had information on hydrogeology available, and of the eight that did not, only four had other information that might be useful for hydrogeological research (see Table 20 in annex 8 of this document).

Figure 10: Total renewable water resources per capita and the indicator of GSO hydrogeological capacity



Source: FAO AQUASTAT (2013), Kay and others (2012)

To asses absolute water scarcity, total renewable water resources per capita was used as an indicator. The data, summarised in Figure 10, show that 21 African countries had less than 1700 m3 of renewable water resources per person per year (FAO AQUASTAT, 2013), ranging from the Seychelles to Comoros. Of these countries, only four had GSOs with information available on hydrogeology: Burkina Faso, Egypt, Ethiopia and South Africa. The remaining 18 had no direct information; nine did not have other information that might be useful for hydrogeological research.

It should be noted that many African countries have extensive water resources. In general, however, countries in North Africa and Southern Africa generally are water scarce, along with small island States.

3.5 Geological hazards

3.5.1 Indicators

Risk and hazard data from the Emergency Events Database (EM-DAT), published by the Centre for Research on the Epidemiology of Disasters, were used to indicate the need for hazards information. The data were compared with the availability of hazards data from African GSOs, which were derived from Geoscience Australia's assessment (see annex 9 to the present document). In their 2012 report, Geoscience Australia defined risk and hazard capacity as the ability to undertake the:

> "Assessment of a range of risk and natural hazard phenomenon, such as volcanic, earthquake, subsidence, flood, tsunami inundation etc. and integrated modelling and mitigation strategies product development. In addition anthropogenic hazards such as extractive industries associated pollution, groundwater contamination, waste leachate, urban development etc. may also be conducted by geological surveys" (Kay, and others, 2012, p.115).

The indicators of hazard information needs were derived from EM-DAT, which recorded the number of people killed and affected by natural disasters along with the cost of these events. Geological hazards covered included earthquakes (see Figure 11), tsunamis , volcanic eruptions (see Figure 12) and both wet and dry mass movement (i.e. subsidence). EM-DAT was also has extensive data on flood events that have affected Africans.

The first indicator of geological hazard information needs was the number of people affected by geological hazards, excluding flooding. It was assumed that countries with the greatest number of people affected by geological hazards would require the most information, both in terms of quantity and quality as well as a greater capacity within their GSO to deliver this.

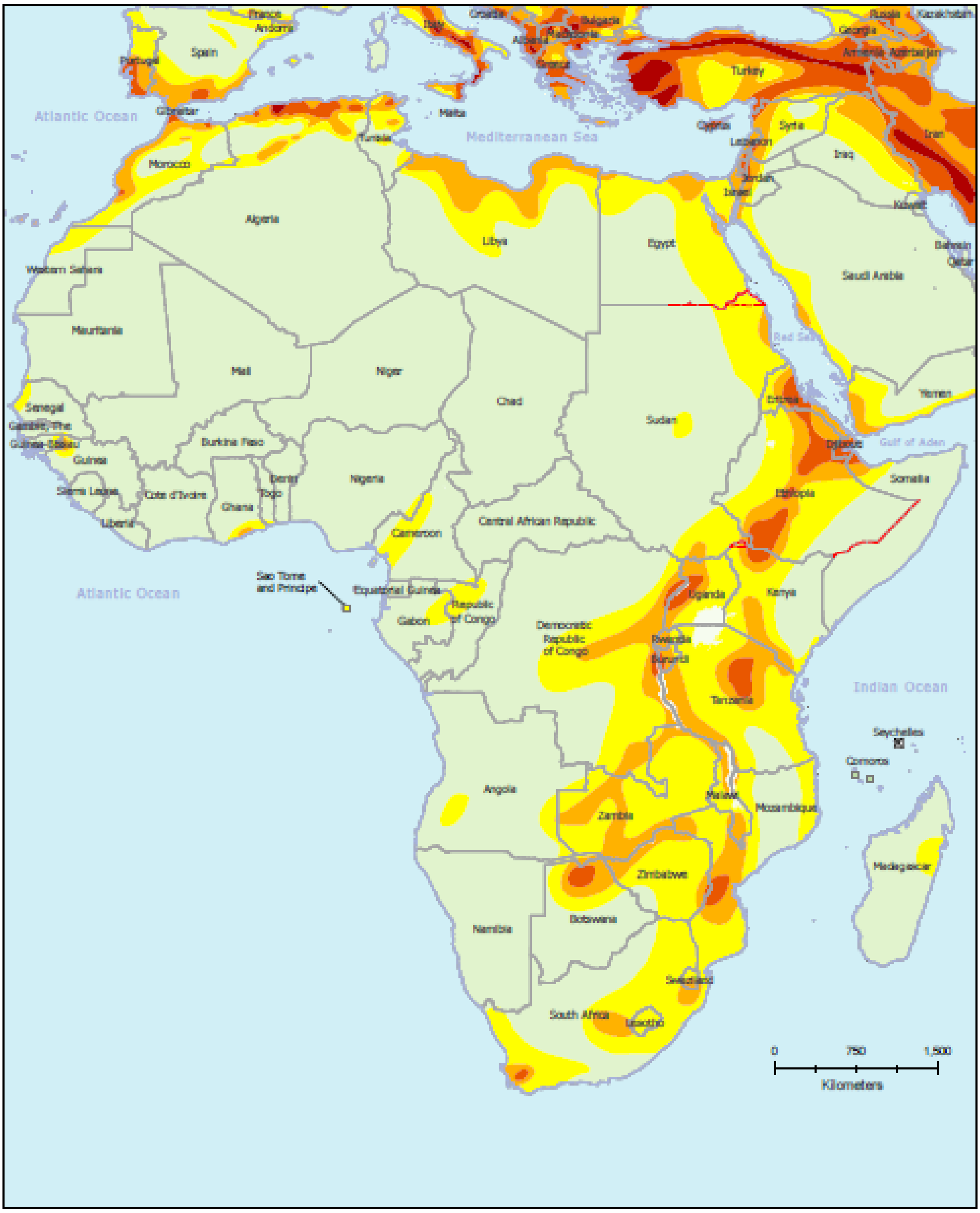
3.5.2 Results

In Africa, since 1900, eight countries have had 50,000 or more people affected by geological hazards, excluding floods: Algeria (1,367,898), Comoros (309,200), Democratic Republic of Congo (193,749), Egypt (93,993), Malawi (70,836), Morocco (50,681), Somalia (105,083) and Uganda (77,103). In total, these countries lost 21,741 lives over 62 separate geological events since 1900 (note that this is almost certainly and underestimation of the numbers of people affected given that the pre-1950 EM-DAT records for Africa are very sparse). Of these eight countries, only the Democratic Republic of the Congo and Egypt had GSOs with information on risks and hazards, while another five had information that might be useful for hazards research (see Figure 13 below and Table 21 in annex 9 of this document).

Geological hazards (excluding floods) affected a minimum of 1,000 to 50,000 people in 12 other African countries since 1900, according to EM-DAT data. A total of 2,761 people were estimated to have died in 54 separate geological events (excluding floods) in these countries. Of these countries, five had GSOs with information available on geological hazards. Of the seven countries that did not have hazards information available, three had other information that might be useful in hazards research (see Table 21 in annex 9 of this document).

These results suggest that Africa has a fairly low geological hazard potential, especially when compared to tectonically active areas, such as the Pacific Rim. However, based on assessments by the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) of seismic (see Figure 11) and volcanic (see Figure 12) hazards across Africa, there are some areas where there are significant populations that might be affected by geohazards in the future. However, it should be noted that collecting reliable historical data on geohazards is difficult and most estimates of those affected or killed with have a significant margin of error.

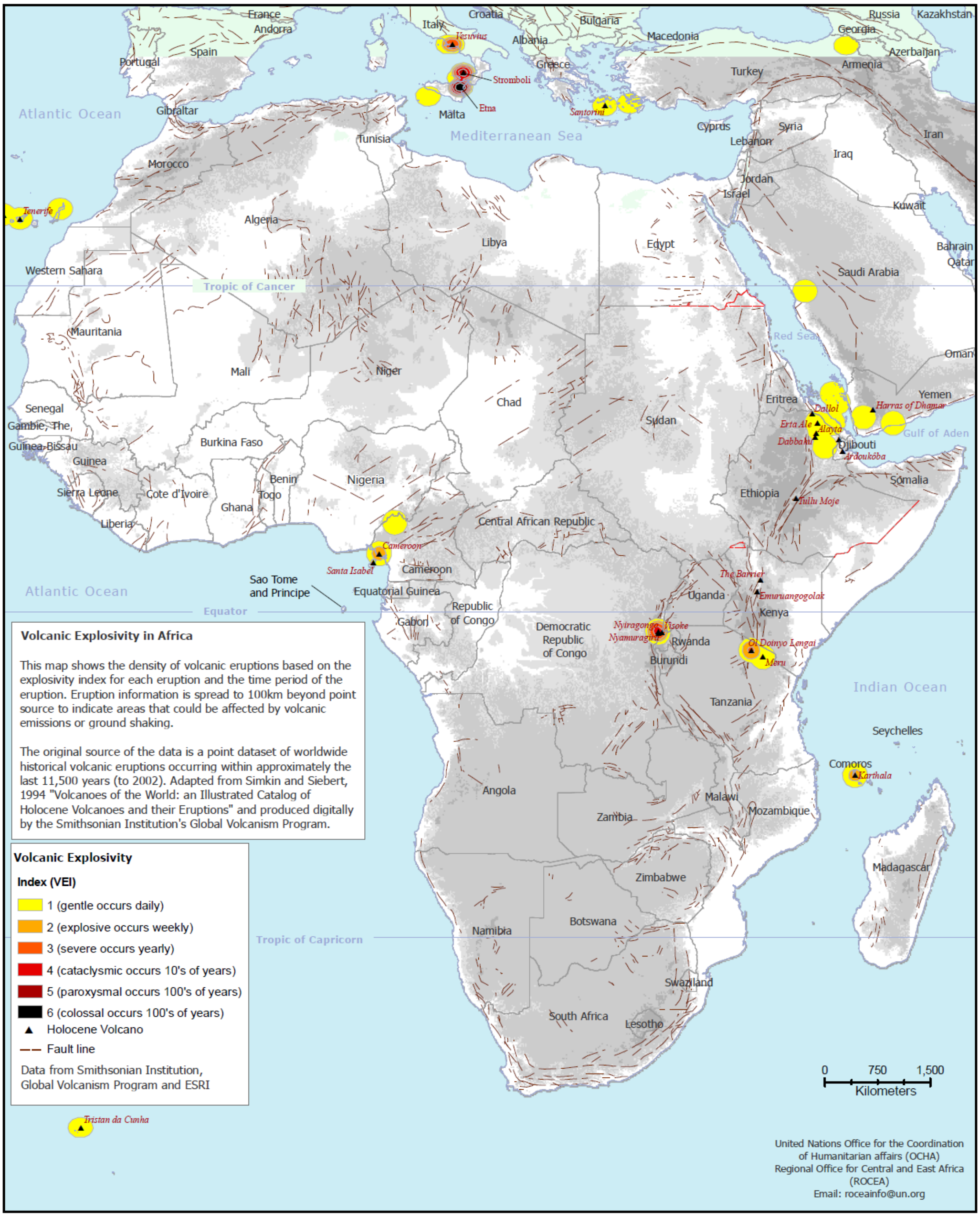
Figure 11: Seismic hazard map for Africa



Source: OCHA (2007a).

Note: The boundaries, the names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

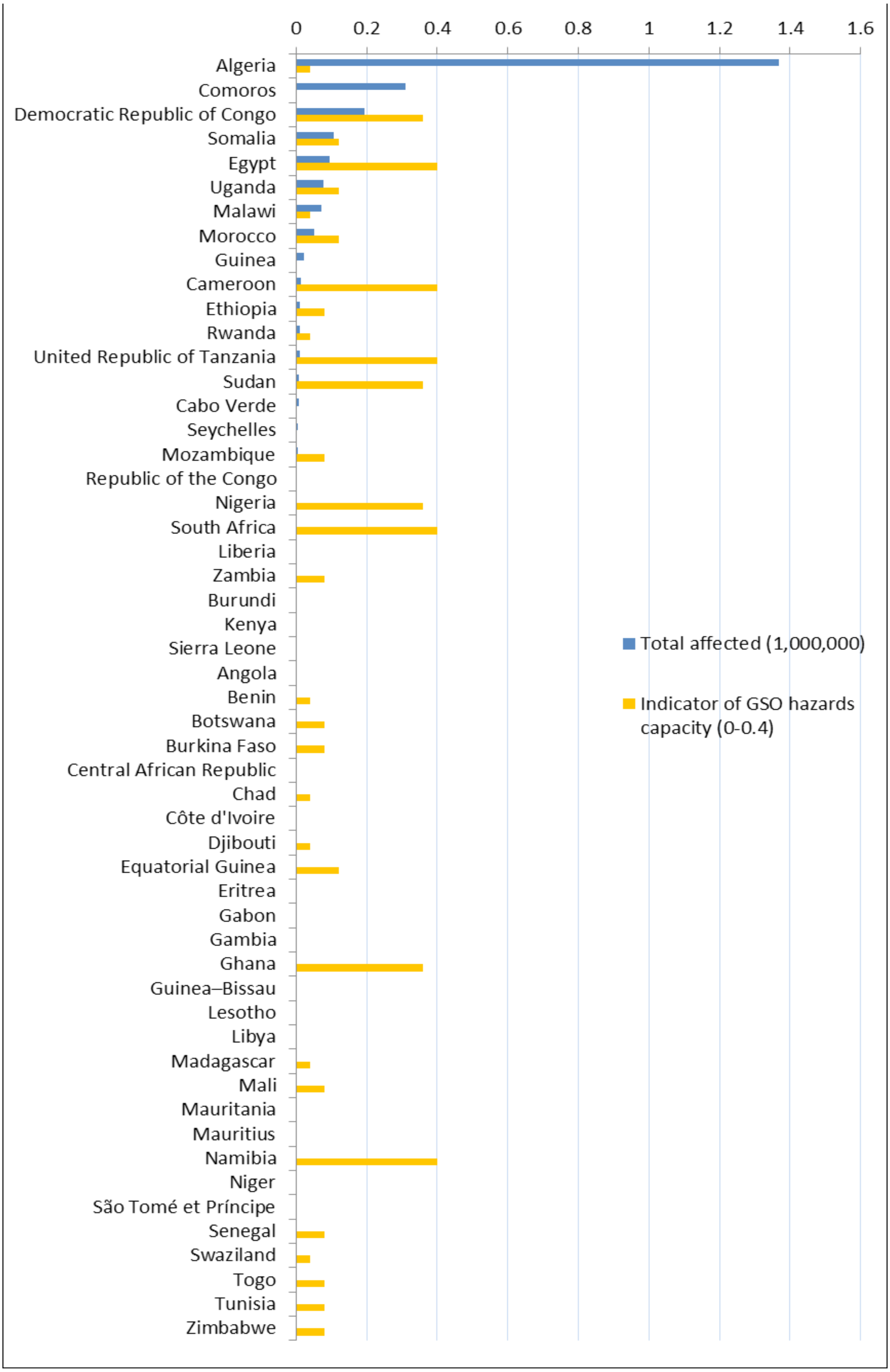
Figure 12: Volcanic hazard map for Africa



Source: OCHA (2007b).

Note: The boundaries, the names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 13: Graph of number of people recorded as being affected by geological hazards (excluding floods) in Africa since 1900 and the indicator of GSO hazards capacity



Source: Emergency Events Database (2013), Kay and others (2012).

3.6 Effectiveness of GSO support

3.6.1 Indicators

To assess the effectiveness of GSO support (e.g. capacity building and other activities), data from the Geoscience Australia 2012 assessment were analysed. The indicators of support provided were based on the Geoscience Australia assessment regarding the amount of "geological aid" delivered through collaboration (see annex 10 to the present document). Geoscience Australia had binary data (yes or no) on World Bank projects related to geology and water, but the data were not used for statistical reasons. The assessment of collaboration consisted of the following categories: major, substantial, significant, minor, and none (see Figure 14).

Ideally, data would have been available on the state of GSO capacities before and after the support was provided, along with the change in assessed mineral potential. However, such information did not appear to exist. Consequently, the Geoscience Australia 2012 assessment of GSO capacities was used as a proxy measure of change in capacity (see Figure 15). Similarly, the Geoscience Australia 2012 assessment of minerals potential was used as a proxy measure of effectiveness (see Figure 16).

3.6.2 Results

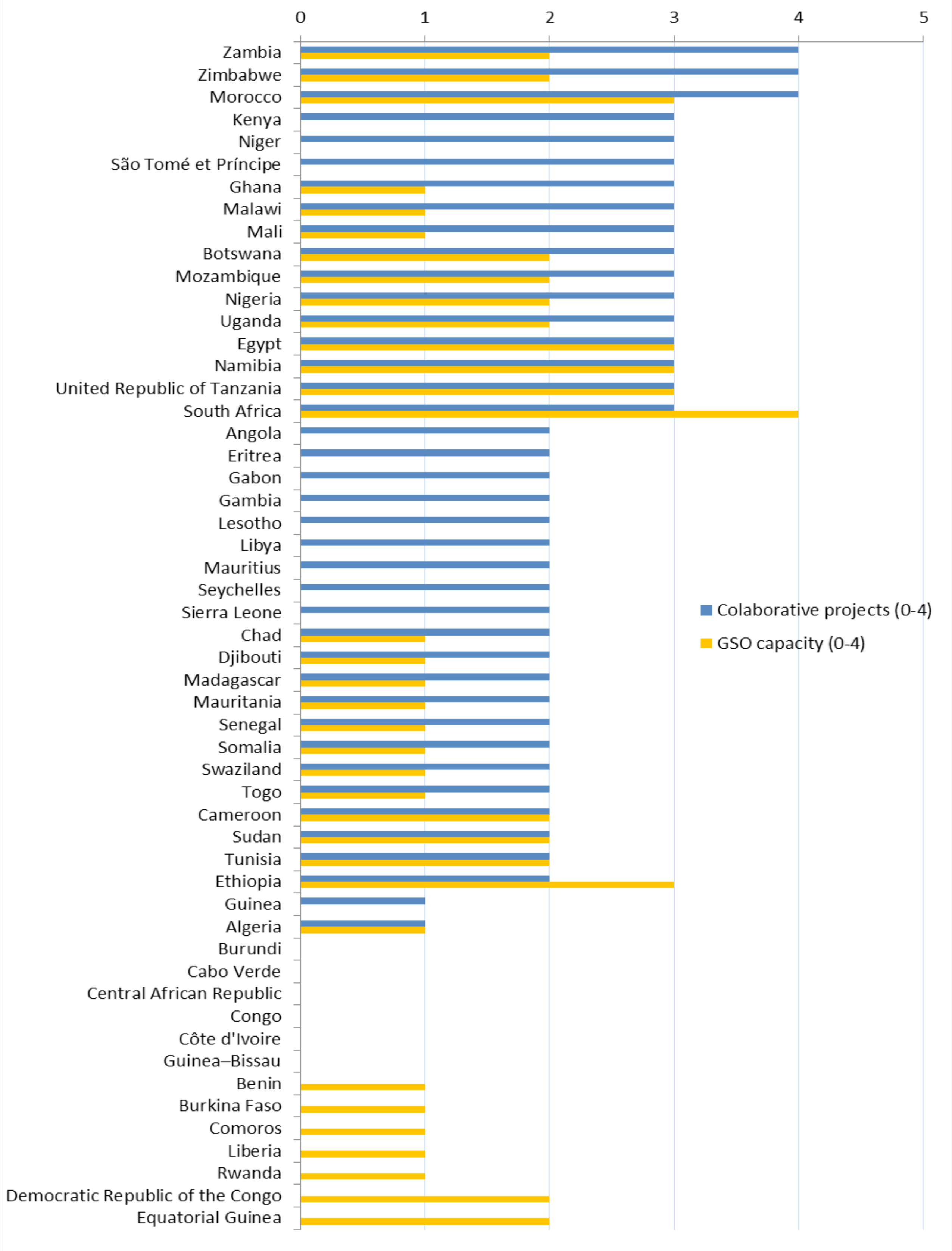
Due to the inherent limitations associated with the utilization of proxy measures, the data could not be used to draw definitive conclusions about the effectiveness of geological aid or support. Nevertheless, some important correlations

Figure 14: Geoscience Australia's assessment of geological aid in the form of collaborative projects

Source: Kay, and others (2012).

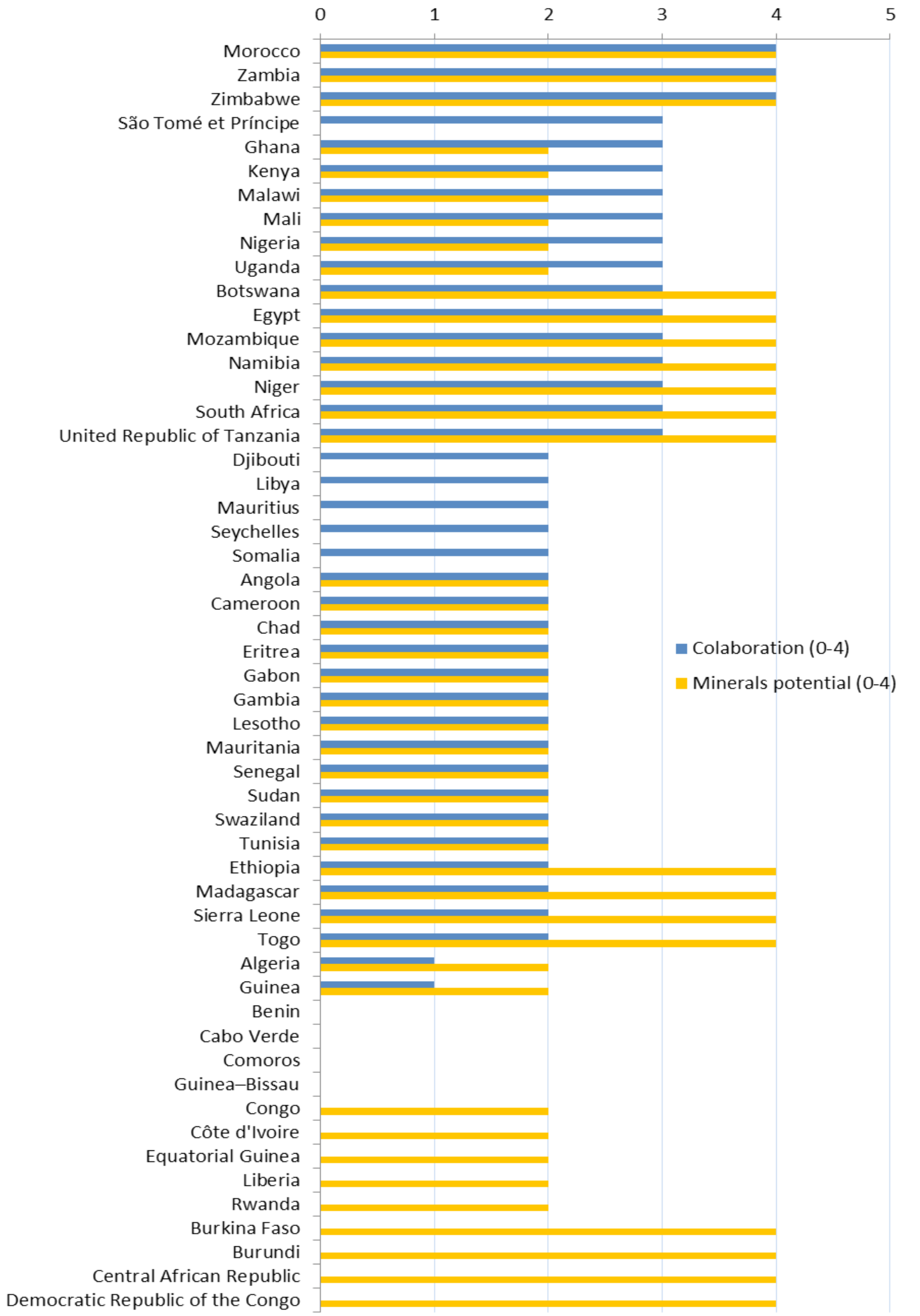
Note: The boundaries, the names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 15: Graph showing Geoscience Australia's assessment of the intensity of collaborative projects relative to GSO capacities in the same countries



Source: Kay and others (2012)

Figure 16: Graph of Geoscience Australia's assessment of collaborative support to GSOs and the minerals potential of countries



Source: Kay and others (2012).

did surface. GSOs that had received support generally had better capacities than those that had not received support or had received less support (see Figure 15). Morocco, Zambia and Zimbabwe were, however, rated by Geoscience Australia as having received major collaborative support, but were only rated as having GSOs with capacity or some capacity to collect and disseminate geological data and information. Four of the five GSOs rated as having either capacity or strong capacity to undertake major geoscientific surveys and disseminate data were rated as receiving substantial collaborative support. Of the 14 GSOs rated as having received substantial collaborative support, three were rated as having no information available or none detected online in English, French or Spanish, while an additional three GSOs were rated as having "limited capacity to undertake geoscientific surveying". Of the 13 GSOs rated as not having had collaborative support, seven were rated with either some or limited capacities to undertake geological surveys. However, five of these countries previously had World Bank support.

Collectively, these results suggest that substantial collaborative support does not guarantee that a GSO will have the capacity to undertake geological surveys and disseminate information. It should, however, be noted that GSOs that had received collaborative support generally had better capacities than those that had not received support. These results likely reflect, at least partially, the broad nature of GSO assistance included in the collaborative support assessment as compared to the more narrowly defined proxies used above.

When looking at the minerals potential in 2012 relative to the collaborative support provided, it is clear that the more support a country receives, the stronger its mineral potential becomes (see Figure 16). This is likely to be, at least partially, a case of the "chicken and the egg" as presumably the countries with the greatest mineral potential are likely to have received geological support earlier and/or to a greater degree than countries with less well known mineral potential.

4 Discussion

4.1 Introduction

The discussion below is framed in relation to the aim of AMDC Results Area 2: Geological and Mining Information Systems: to improve information on minerals for development in support of AMV (see AMDC, 2012, p.21).

The AMV states that "African states lack basic geological mapping or, at best, are poorly mapped". It was noted in AMV that the level and quality of mineral resource potential data is a key issue for realising AMV, especially since resource data affects the ability of African countries to attract investors and negotiate favourable resource rents for the country and its people.

In what follows, GSO capacities are reviewed, the gap between geological information needs and available geological information to support development and minerals industries is examined. From this tentative next steps are suggested.

4.2 Geological information systems and development

The relationship between geological information systems and development is complex. The link includes better minerals information being used to improve contract terms, conditions and resource rents for African governments and their people, as well as ensuring that there is good information for artisanal miners (AMV, 2009). This information needs to be coupled with good governance and public participation to ensure resource rents and investments in public goods actually end up supporting widespread development (see Figure 17).

Another way GSOs can support development is through the provision of information on renewable and non-renewable energy resources, hydrological systems and groundwater as well as geological hazards and geotechnical information. These types of data and information can help improve access to natural resources and when coupled with planning processes, can improve the resilience of development (see Figure 17).

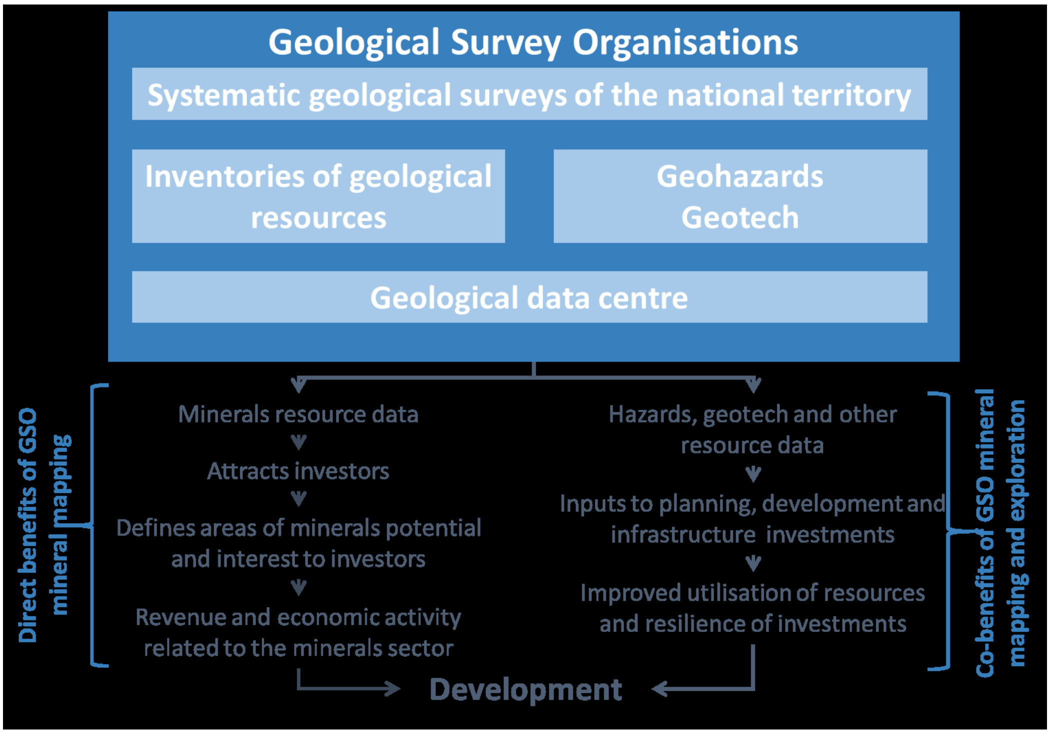
EI Source Book (2012) examined the impact that good geological data might have on attracting investment and found that it helps to attract investments when investments are being made. However, information alone will not attract further investment if the minerals industry is going through a "bust phase" (i.e. when prices are dropping or are low) or other investment deterrents are present.

4.3 Minerals data needs and gaps

Before discussing minerals data needs and gaps, it is important to note that there are many types of minerals, including ore minerals, industrial minerals, agro-minerals, gems and semi-precious stones. For each of these minerals there are different data needs, both for board room decisions prior to exploration and for decisions on going ahead with mining and processing.

Nearly half of all African economies (22 countries) rely on mining, quarrying and petroleum for 5 per cent or more of their GDP. Only three of these countries, specifically Egypt, Namibia and South Africa were rated by Geoscience Australia as having GSOs with either strong capacity or

Figure 17: Generalised diagram showing the relationship between minerals and other information from GSOs and development.



capacity to undertake surveys and disseminate data (see Figure 1). This suggests that there is a lack of public investment in the acquisition and provision of geological data that can be used to ensure the sustainability of minerals industries in African countries, for example by attracting new exploration or increasing the chances of new mineral finds.

Some countries may have minerals potential but do not yet have established mining industries at either the industrial or artisanal scales. For the 18 African countries rated by Geoscience Australia as having "proven substantial resources and production of mineral commodities", five were rated as only having some capacity to undertake surveys and disseminate data, three were assessed as having limited capacity to undertake surveys and four were rated as either having no information or information was not detected. Similarly for the 23 African countries that were rated as having "potential with some known resources or production of mineral commodities", five were rated as having some capacity to undertake surveys and disseminate data. Ten were assessed as having limited capacity to undertake surveys, and eight were rated as either having no survey data or data could not be detected. These results suggest that where there is potential for new minerals development, there may be a fundamental lack of information available to attract new investment or expand current production.

The fact that investors continue to invest in minerals in Africa suggests that industry experts (not governments) hold at least some of the information required to attract minerals investment. Geoscience Australia's assessment of GSO capacities reinforces the study by BGS, which found that in comparison to other parts of the world African GSOs, with a few exceptions, generally have weak capacities (the exceptions being Egypt, Ethiopia, Morocco, Namibia, South Africa and the United Republic of Tanzania).

The 2012 EI SourceBook survey of the minerals industry in Africa found that African countries, in general, had poor quality, difficult to access geological data. Botswana and Namibia were notable exceptions. Both were praised for their ease of data accessibility and open data policies.

As part of the EI Source Book survey, respondents were asked about the types of information they needed most, and how they would use this information. From the survey results, airborne geophysical data, maps of mineral occurrences and geology in electronic vector based GIS formats were deemed to be high priorities. For boardroom decisions on which prospects to take on, it was noted that maps should be at scales of 1:500,000 or better and regional airborne geophysical data are sufficient. For exploration purposes, geological maps at scales of 1:200,000 are useful but scales of 1:100,000 or better are optimal. Airborne magnetic and radiometric data collected by flying lines 800 m apart are sufficient but lines flown 400 m apart are most useful. For petroleum exploration, gravity data are preferred with similar line spacing.

It is important to note that some assessments of GSO capacities seem to focus implicitly on ore minerals without paying as much attention to industrial minerals, agro-minerals, or gems and semi-precious stones. Given the stages of development that many countries in Africa are at, industrial minerals (e.g. for construction) or agro-minerals may be very important for countries to achieve their infrastructural and agricultural targets and goals (see Van Straaten, 2002).

4.4 Co-benefits of minerals data activities

The primary focus of the work of AMDC is in the area of geological and mining information systems regards data and other information that can be used to support minerals exploration and extraction. Mapping, geophysical data acquisition, remote sensing and other activities useful for generating information on minerals can, however, result in co-benefits that can positively impact other areas, such as petroleum geology, hydrological information, the assessment of geological risks, hazards and geotechnical issues, among others. For example, remote sensing data can be used to identify rock structures that may contain valuable minerals, but at the same time if the person making the interpretation is trained in hydrogeology they might also record the apparent sources of streams and other features that might give clues to the presence of groundwater.

In order to maximise development returns from investments in minerals information capacity and data acquisitions it is important to be aware of hydrological, hazards, geotechnical, geothermal and other energy needs that might also benefit from minerals related geological mapping and surveys. And, as the gap analysis has shown, some countries have a greater need than others for minerals information.

4.5 Other data needs and gaps

There are some important information needs across African countries related to energy as well as hydrogeology and hazards.

4.5.1 Energy

A range of potential energy resources exist in Africa, such as petroleum, geothermal energy and hydro-electricity. GSOs have a role in storing and sharing data that can support the development and utilisation of these resources, for example seismic data for petroleum; volcanic features and geothermal gradient information for geothermal electricity and direct use projects; and geotechnical information, maps and hydrological information for hydro-electricity and water reservoir related projects.

There is significant interest in petroleum in Africa generally, especially as large resources are found in new places. As the petroleum industry is at a relatively early stage of development, the current reserve estimates are unlikely to provide a full picture of the regional petroleum potential. This clearly indicates that there is a need for more petroleum information in Africa. On this point, Geoscience Australia found that only 7 of the 19 countries that had existing petroleum industries had information available on energy.

Most of the geothermal energy potential in Africa is concentrated along the Rift Valley. Thirteen countries were identified as having geothermal potential (see Table 13). Of these, two were producing geothermal energy, specifically Ethiopia and Kenya, with 7 MW and 209 MW of installed capacity respectively (Teklemariam, 2010). Of these two, only Ethiopia had energy and hydrological information available. Of the other 11 countries with geothermal potential, only the United Republic of Tanzania had information on both energy and hydrogeology, while the Democratic Republic of the Congo and Mozambique had information only on hydrogeology. The remaining countries lacked data on both energy and hydrology.

Countries with the greatest hydro-electricity potential tended to have better availability of information that might be useful for such projects. Fourteen African countries either had installed capacities or the potential for a total installed hydro-electric capacity of greater than 1 GW (i.e. 1000 MW), ranging from the Democratic Republic of the Congo (6.1 GW) to Zimbabwe (1.2 GW). Of these 14 countries, six had information on four main areas: geology, hazards, hydrology and mapping. Two countries had information on three of these four areas, and five countries had information on two of the four areas.

Energy is essential for development and not only to power industrialisation, but also to power households and agricultural production, for example irrigation pumps. GSOs have an important role in informing both renewable and non-renewable energy developments, for example related to petroleum and coal, as well as geothermal energy, hydro-electricity and uranium for nuclear power. The present GSO capacity assessment makes clear that more energy related information is required from GSOs in African countries with petroleum, geothermal, hydroelectric and other geological energy potential.

4.5.2 Hydrogeology

Many countries in Africa, especially those in northern and southern Africa, are water stressed. Many other African countries have a relative abundance of water in absolute terms, even if much of it is not utilised. Of the 21 African countries that had less than 1,700 m3 of renewable water resources per capita per year (see Figure 10 above and Table 20 from annex 8 of this document), only four had GSOs with information available on hydrogeology: Burkina Faso, Egypt, Ethiopia and South Africa. The remaining 18 had no direct information but nine had other information that might be indirectly useful for hydrogeological research.

In five African countries (Burkina Faso, Burundi, Comoros, Libya and Rwanda) groundwater resources comprised over 50 per cent of their renewable water resources. Of these countries, only Burkina Faso's GSO had specific information on hydrogeology, according to the Geoscience Australia assessment (Kay, and others 2012). Rwanda had other indirect information that might be useful for the purposes of hydrogeological studies.

The Geoscience Australia study shows that GSOs in Africa do not have sufficient hydrogeological information available to them. However, it may be that other institutions outside of GSOs compensate for this and have more hydrological and hydrogeological information available. At a minimum, it can be concluded that GSO hosted hydrogeological coverage across Africa is limited.

4.5.3 Geological hazards

Geological hazards in Africa are relatively minor compared to other more tectonically active parts of the world, as shown in seismic and volcanic hazard maps for Africa (see Figures 11 and 12). However, geological hazards may pose significant "local" risks as evidenced by the estimated number of people affected by geological hazards (see Figure 13). Algeria has been particularly affected, especially by seismic events. Eight African countries had an estimated 50,000 or more people affected by geological hazards (excluding floods) since 1900, consisting of: Algeria, Comoros, Democratic Republic of Congo, Egypt, Malawi, Morocco, Uganda and Somalia. Of these eight countries, only two (Democratic Republic of the Congo and Egypt) had GSOs with information on risks and hazards, while another five had information that might be useful for hazards research (see Figure 13 above and Table 21 in annex 9 of this document).

The gap analysis shows that GSOs in Africa, in general, lack information on geological hazards. Geological hazards are not, however, a significant issue in many countries compared to other types of hazards. It is important for GSOs to keep information on geological hazards that might occur in specific geographical areas, such as areas vulnerable to earthquakes, volcanic activity and tsunamis.

4.6 Filling the gaps

While it is possible to get some indication of the minerals, energy, hydrological and hazards related geological information needs for African countries using the indicators discussed above, along with a sense of GSO capacities as rated by Geoscience Australia, the amount of information required to fill information gaps will vary between countries depending on what information countries already have, the size of the country and the type of minerals they need information on, such as ore, industrial minerals, agro-minerals, gems or semi-precious stones.

At least three studies have looked at the issue of map coverage: Dixey (1963) summarised geological, geophysical and other geology related map coverage; Temple (1965) reviewed the status of mapping in Kenya, Uganda and the United Republic of Tanzania; and BGS (see Reedman, and others, 1996) assessed 10 African countries along with countries from other parts of the world. Temple (1965) noted that issues surrounding the quality of information generated and data coverage needed to be considered. Specialist quality assessments are, however, beyond the scope of the present report. Thus, our assessment focuses on data coverage.

To give a sense of the geological information provision challenge facing Africa in 1996, BGS found that "The ratio for the African and European Union GSOs are 1 graduate per 6,294 km^2 and 1 graduate per $995km^2$ respectively, though the remaining surveying task in Africa, at the scales indicated, is six times larger in Africa than in Europe" (Reedman, and others, 1996, p.15). The assessments by AMV (2009) and Geoscience Australia (Kay and others, 2012) presented a similar picture and indicated that providing geological information on Africa was an ongoing challenge in spite of recent advances in GSO performance and donor assistance activities.

The 1996, BGS attempted to investigate the underlying reasons for the relative weakness in many African GSOs. One key reason appeared to be a lack of professional staff, a situation exacerbated by low pay relative to that of the private sector. This echoed Dixey's recommendation, made in the early 1960s, that pay and conditions need to be improved (see Dixey, 1963). Furthermore, budgets for survey activities are very small, which frustrates GSO staff.

Various forms of support can be offered by development partners and accessed by individual governments and GSOs, including general budgetary support, support for specific projects that might include budgetary and technical advice, or support in the form of having another party undertake geological research on behalf of the country. Both Dixey (1963) and Reedman and others (1996) suggested that a particularly effective form of support is having long-term professional linkages between two or more institutions where technical capacity exchange is fostered. A key challenge is to ensure that the support being offered and provided matches needs. The risk exists that the geological support might be supply driven rather than demand driven, potentially distracting GSOs from working on real priorities.

The Zambian case study highlighted information management issues. For example, the lack of data standards being used meant data could not easily be integrated or used to produce coherent maps. Maintenance of databases and information systems was another issue identified. The International Mining for Development Centre is working with the Government of Zambia on these issues, and there may be a need for similar standards, policies and practices to be implemented in other GSOs. Without performing GSO specific needs assessments it is difficult to generalise. It is, however, important to work with each country to identify their specific information needs and current capacity before embarking on any capacity building assistance programs.

Based on survey and other information, a sequence of four activities (stages) to improve geological data accessibility for mining companies and governments were highlighted in the EI Source Book (2012):

1) Compile existing geological maps and reports and reprocess existing airborne geophysics with the synthesis information presented in resource prospectivity reports, booklets and brochures;

2) Digitisation and reinterpretation of colonial era maps, including maps held by countries outside of Africa (this should include limited groundtruthing based on field mapping of key locations to ensure reinterpretations match reality);

3) Acquire high resolution airborne magnetic and radiometric data for minerals and gravity for petroleum(with sufficient interest and available finance this could be done for a country, zone or for a smaller set of target areas);

4) Develop high resolution geological maps drawn from information in steps 2 and 3 above and other research.

While the list of activities above is presented in numerical order there is no reason why activities cannot be taken concurrently in some cases or airborne geomagnetic information can be acquired where this looks likely to yield most benefit. Given the effort required to find existing geological information and reprocess it, it may be more cost effective to acquire new, high quality data and work with GSOs to process it.

In addition to the points listed in the report by the EI SourceBook (2012), reviewers suggested that it might also be important to:

- Establish and maintain a regional metadata clearinghouse(or a series of clearinghouses) to help users find geological datasets;
- Engage in regional geochemical surveys for mineral exploration and establish baselines for environmental impact assessments.

Compiling a national catalogue of available geological information (essentially creating a metadata clearinghouse) and providing information on how to access it was mentioned in the EI Source Book as a means to facilitate the access to geological data.

GSOs should not, however, accept all of the available support; rather, they should appraise with technical partners on what technical support would be most effective in meeting GSO and national objectives. With regard to the study by BGS, it was noted that "…both GSOs and donors should be careful that technical assistance inputs into a particular core activity do not make such demands on the GSO's limited resources that the core programme is distorted and parallel activities are damaged" (see Reedman, and others, 1996, p.28). Technical assistance provided by partners should be aligned with needs of GSOs.

Ideally, interventions in support of GSOs will lead to long term and sustainable improvements in capacity. It was noted in the study by BGS that in some cases it may be justifiable to work with a GSO on a joint project that has a very small chance of sustainable capacity improvement. Such examples include projects that: attract significant investment, help to resolve a time-dependent issue such as water scarcity, or leaves a dataset of long term value such a comprehensive geological map.

4.7 Potential effectiveness of collaborative support

GSOs that received significant support generally had better capacities than those that had less support or no support at all (see Figure 15). At the same time, this shows that collaborative support does not guarantee that a GSO will have long lasting improved capacity to undertake geological surveys and disseminate information.

When looking at the minerals potential in 2012 relative to collaborative support provided previously (see Figure 16), it is clear that the more support a country receives, the more likely it will have stronger potential, but there is a question as to whether it was the minerals potential that first attracted the support.

It was noted by EI Source Book that there have been many development assistance projects related to geological information in Africa and that these may have led to short term improvements. In many cases, however, the improvements in long term information provision were less than desired. It was suggested that any development assistance to GSOs should have a clause to ensure information will be freely and publically available.

According to the EI SourceBook, in some cases respondents to the survey indicated that either the GSO sold data and this provided much needed income for the GSO or in other cases GSO staff sold information without receipts and for cash only. Thus, vested interests, incentives and the need for well financed African GSOs are things that need to be addressed if GSOs are to become effective, efficient and trusted with the collection and disseminating geological information.

4.8 Spatial data infrastructure

SDI that allows integration of geological data with other data from various sources and scales is critical for assessing development options and making informed decisions. Several NSDIs are in progress in Africa (e.g. in Nigeria, Kenya, Rwanda and Uganda). Many challenges face NSDIs, such as institutions not sharing data or having data that is incompatible with current formats and standards, a need for reliable Internet connections, and suitable technology and human capital to support initiatives, among others. Despite these challenges, the potential benefits of NSDIs will likely result in ongoing efforts to establish and maintain NSDIs, and GSOs should be an essential part of NSDIs in terms of providing geological and hydrographic information, which are fundamental spatial datasets (ECA, 2007).

4.9 Development applications

According to Geology for Global Development (2014), geological information is essential for finding mineral resources, as well as agriculture (i.e. agri-geology), water and sanitation (e.g. hydrogeology), infrastructure, managing geohazards and climate change. However, the examples cited are restricted to important technical applications but do not address how geological information can be used to inform policy or broader development planning.

Artisanal and small-scale mining (ASM) is often undertaken in a wildcat manner and could potentially benefit from minerals information, along with improved policies and license arrangements for ASM. ASM areas that are based on better mineral resource information could transform ASM from being an especially risky business (e.g. risky in terms of finding and following resources in addition to health and other issues) to being a business with risks similar to those faced by industrial scale miners.

Public minerals information plays an important role in informing people and communities about possible mine developments and where they might occur. However, minerals information needs to be coupled with expectation management. People and communities must have realistic expectations regarding the benefits that might arise from proposed mining projects. For example, due of the high cost of capital most of the profits from mineral projects are used to pay for capital. Only a fraction of the profits remain in local communities or are captured as resource rents, which could be used to pay for public services at the national rather than the local level.

Given the inherent uncertainty surrounding mineral resources being realised and mined, it would seem there is scope for geological resource data to be coupled with infrastructure, industry, environmental and other data to prepare development scenario analyses and assess development issues and options. In order to help countries prepare for mining, development scenarios should address several important questions before project implementation, among them:

- What infrastructure might be needed if resources are to be mined in one part of a country versus another?
- Is it economically viable for infrastructure to be put in place?
- Are there sensitive ecological areas nearby and what are the environmental risks?
- Are there existing economic activities that might benefit from or be disadvantaged by the introduction of mining?

These are the types of questions that development scenarios might address and help countries better prepare for mining, rather than responding to issues as they arise. The development of Country Mining Visions (CMVs), in support of the AMV, offer an opportunity to engage in mining scenario analyses (see CMV Guidebook, 2014).

Such scenario analysis might be used to better plan corridors of development and industrialisation in relation to mineral resources and potential mine sites. Mineral resources, including potential resources, and their locations should form an important part of planning processes related to these corridors, the infrastructure required. The potential of such resources being realised affects the likelihood of developments being realised.

Finally, it was noted in the EI SourceBook that minerals "...activities can bring more costs than benefits to the country that hosts them". This is one reason why the AMV was adopted by African Heads of State and why the AMDC is supporting the development of CMVs. The process of developing CMVs helps moderate expectations and identifies development issues and options that feed into policy, legislation, regulation and practices in African countries. Under a CMV, mining should be aligned with national development priorities. If agriculture is a priority then information on agro-minerals may be a priority (Van Straaten, P., 2002) or if infrastructure is a priority then the location and quality of aggregate and construction minerals should be a priority. In terms of institutional capacities, industrial minerals, agro-minerals, gems and semi-precious stones are generally less demanding to regulate compared with many metallic minerals that often require significant institutional capacities. In this light, GSOs and geological information coupled with other institutions and policies are key for countries to realise the benefits of mining without undue negative environmental, social or other impacts.

5 Conclusions and next steps

Nearly half of all African economies rely on mining, quarrying and petroleum for 5 per cent or more of their measured GDP. Nevertheless, AMV found that "African states lack basic geological mapping or, at best, are poorly mapped," a finding that is reflected in other studies, including the study by BGS in 1996 and the Geoscience Australia study in 2012. The potential benefits of having geological information extend well beyond mining. While the primary focus of AMDC is on minerals and development, there are co-benefits that might be achieved through geological mapping, geophysical surveys and other data collection activities. For example:

- Minerals information can attract investments in industrial and artisanal mining meanwhile better resource rents coupled with good governance can be used on public services and infrastructure investment;
- Energy information can help countries extend or initiate petroleum exploitation, or help identify new and renewable hydro-electricity and geothermal energy resources to power industrialisation, agriculture and households;
- Hydrogeological and hydrological information can assist with the discovery of new water resources in water scarce areas and foster better management of water resources for agriculture, mining, electricity and other uses;
- Hazards and geotechnical data can be coupled with planning processes to improve the resilience of all forms of development.

The gap analysis shows that many countries with existing mineral industries are risking the sustainability of those industries due to a lack of public geological information. Furthermore, other countries with the potential for minerals development may also be postponing the establishment of new artisanal and industrial scale minerals development due to a lack of geological information. Across Africa there are a series of potential co-benefits that could be realised if sufficient geological information were available (e.g. along the Rift Valley in East Africa there is significant geothermal energy potential). It is important to note that different data needs exist for different types of minerals, including various ore minerals, industrial minerals, agro-minerals, gems and semi-precious stones.

Given the potential development benefits that could derive from better minerals information, AMDC should take a strategic approach when working with GSOs and other partners to maximise the potential benefits of geological data. As the Zambian case study highlighted, to maximise the value of data it is important to acquire quality data and have good data management practices, templates and standards for the collection of data by GSOs. This necessarily includes metadata and other details that allow the interpretation and integration of data from multiple sources, allowing a full picture of the geology of a country to be understood. On this point, AMDC should engage in a review of African and international best practices, policies and procedures, and work with other partners from within and outside of Africa to address geological information practices.

The study by BGS demonstrated that GSO capacities may be limited by more than data protocol issues. Many African countries are geographically very large but have limited GSO staff numbers. Furthermore the mining industry may draw staff away from GSOs as mining companies have substantially greater benefits in terms of pay and the ability to undertake exploration and geological activities.

Each GSO has a different set of institutional arrangements, as well as different strengths, challenges and information needs to address (e.g. some countries will need to focus on industrial minerals for construction while others may have significant precious metals potential to be explored).

GSO capacities should be addressed on a case by case basis. Upon request from member States, AMDC and other partners from within and outside Africa can work with GSOs to examine and improve their:

- Institutional arrangements;
- Existing capacity and areas for improvement;
- Data management systems and standards, including the reporting from mining companies;
- Technologies used and potential upgrades;
- Existing data, data needs and data gaps;
- Potential data acquisition programs to address data gaps.

To support this process, AMDC should compile and compare GSO best practices from within Africa and abroad, allowing comparisons and serving as templates that GSOs might adapt to their needs. AMDC should also compile examples of GSO institutional arrangements and organisational structures of GSOs in Africa and abroad. Further, AMDC should collect standards used to manage geological and related data, and compile principles, policies and practices related to the management of GSOs within Africa and internationally. These documents and examples should serve as reference points when working with countries, GSOs and other partners.

Other areas of support that may be particularly useful include cataloguing what African geological data exists and how it can be accessed, creating professional exchanges and strengthening professional geological associations. At the other end of the support scale, large scale data acquisition holds the potential to dramatically improve the coverage and understanding of African geology, while at the same time providing opportunities for GSOs to further enhance their capacities and attract investment in new exploration.

The gap analysis provides evidence of a correlation between the level of collaborative support provided to GSOs and GSO capacities. This is encouraging. However, there are examples where collaborative support does not appear to have led to significant increases in either data availability or GSO capacity. It is, therefore, important to be aware of previous initiatives and what has worked in the past, along with the limitations of such support in improving GSO capacities.

This report has provided many useful insights on the relationship between minerals and development, set forth various options for supporting geological and mining information systems, assessed the effectiveness of geological support and illuminated potential traps. There is, however, a pressing need for AMDC to go beyond what is already known, find ways to better support GSOs in Africa and optimise the benefits of GSO support activities to member States. The AMDC will use the outcomes of this report to develop a Geology and Mining Information Systems Strategy document. The strategy will delineate how AMDC intends to engage with GSOs in the context of AMV. Thus, until the AMDC Geology and Mining Information Systems Strategy is prepared, the next steps discussed in this report are tentative.

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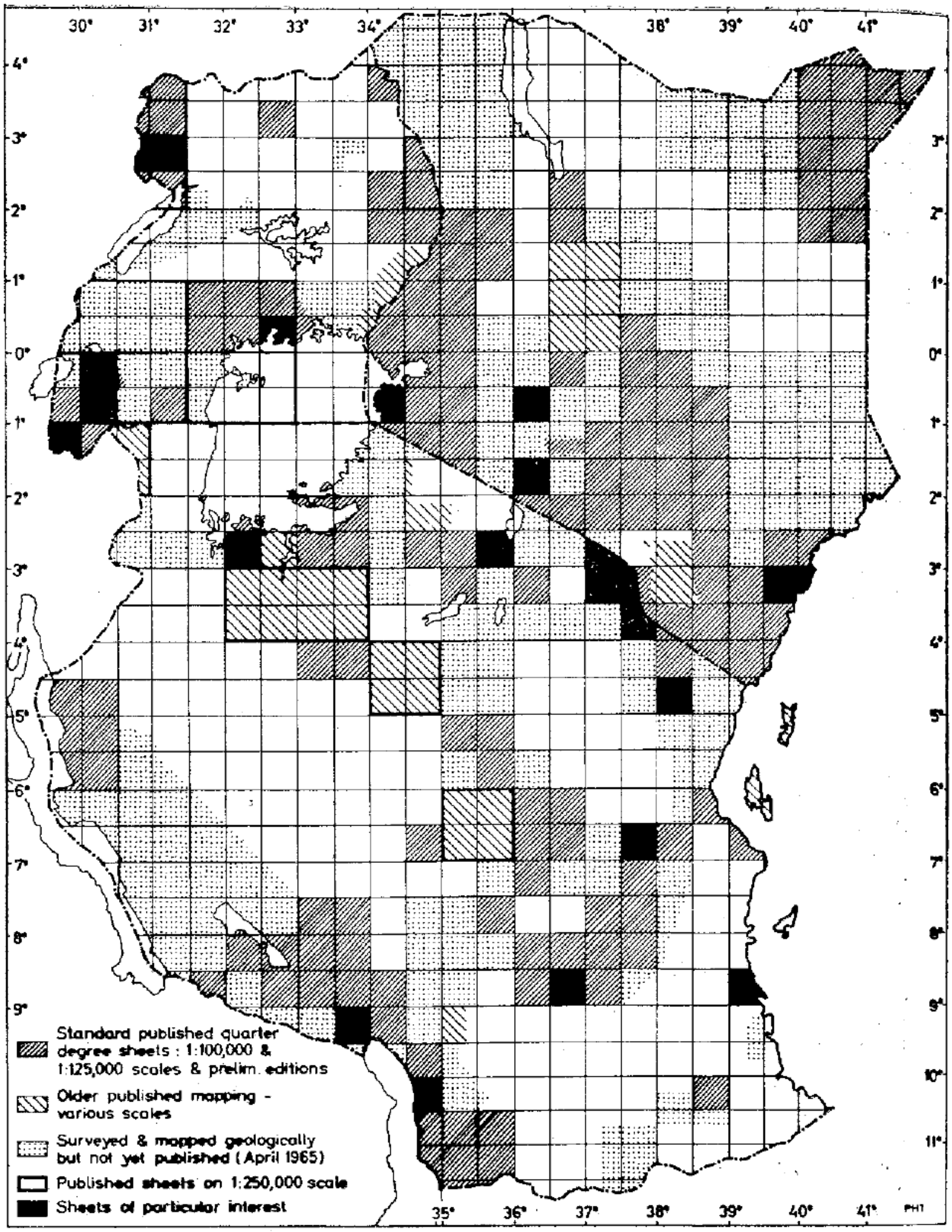
Annex 1: Coverage and scale of mapping in East Africa in 1965

Figure 18: A status map of East African primary and basic mapping at April 1965



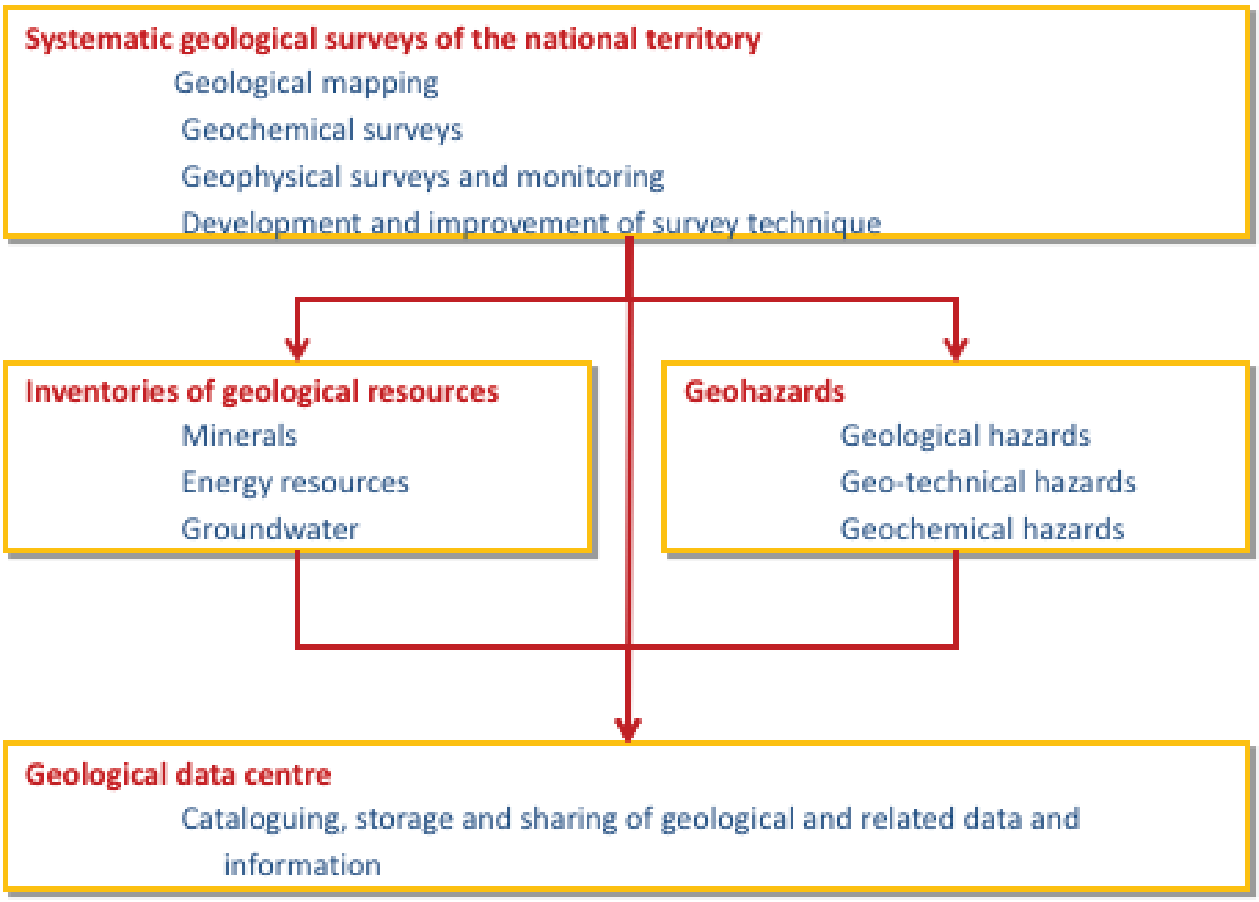
Note: The boundaries, the names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Source: Temple (1965)

Annex 2: Core functions of GSOs identified by the BGS study

From the BGS study of GSOs from developing countries, core functions and programmes of geological surveys were found to consist of: conducting systematic geological surveys of the national territory, developing and maintaining inventories of geological resources, identifying and mapping geohazards, and acting as a geological data centre (see Figure 19).

Figure 19: Summary of four main functions and programmatic areas of GSOs



Source: Adapted from the results of Reedman and others (1996).

The survey results regarding the activities of the GSOs are presented in aggregate for all 31 countries. All GSOs reported that they were undertaking mapping activities. 80 percent reported conducting on shore mapping activities; less than 50 percent of maritime nations reported undertaking marine mineral or energy resource mapping presumably due to the expense of such research. All GSOs had a data centre function. However, the types and quantity of data varied significantly along with the degree to which the data were systematically organised and managed. There was also significant variation in the accessibility of data.

Annex 3: Results of the BGS study of GSOs in developing countries

Table 14: Key findings regarding GSOs in developing countries from across the globe

Functions	Key results of the survey of GSOs in developing countries
Systematic geological surveys of the national territory	• All GSOs surveyed claimed to carry out programmes of onshore geological mapping; • Less than fifty per cent of maritime nations claimed to carry out programmes of offshore geological mapping; • Seventy five per cent of respondents claimed to have the capacity to carry out systematic geochemical or geophysical surveys; • Less than fifty per cent had facilities for processing remotely sensed data, such as satellite imagery or air photographs.
Inventories of geological resources	• Mineral resource surveys and assessment were undertaken by 80 per cent of the GSOs; • Over 80 per cent of GSOs claimed to undertake some work related to other energy sources of one kind or another; • 50 per cent of the respondents carried out programmes that specifically targeted hydrocarbon exploration and assessment; • Less than 50 percent of the GSOs covered by the survey carried out programmes concerned with groundwater.
Geohazards	• Virtually all GSOs had a programme concerned with one or more geohazards; • The scale and nature of these programmes depended on the vulnerability of each country to the various hazards.

Geological data centre	• All the GSOs held geoscience data and therefore were considered to be 'Geoscience Data Centres';
	• There was a wide variation in the:
	    • Types and quantity of data;
	    • Degree to which the data were systematically organised and managed;
	    • Accessibility of data.

Other functions	• Slightly less than 50 percent of the GSOs were responsible for issuing exploration licences, and 50 percent were responsible for the compilation of production statistics.

Source: Adapted from Reedman and others (1996).

Annex 4: Geoscience Australia's assessment of GSO capacities and information availability

GSO capacity ratings:

1. Strong capacity to collect and disseminate high quality geoscientific data and information;

2. Capacity to undertake major geoscientific surveys and disseminate data efficiently;

3. Some capacity to undertake major geoscientific surveys and to disseminate data;

4. Limited capacity to undertake geoscientific surveying;

0. No geological survey detected, or no information available.

Table 15: Geoscience Australia's assessment of GSO capacities and information availability in Africa

Country	Ranking	Geology	Geophysics	Marine	Hydro-geology	Risk and hazards	Remote sensing	Mapping	Mining	Energy	Publication	Website in English
GSOs with a strong capacity to collect and disseminate high quality geoscientific data and information												
South Africa	1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
GSOs with the capacity to undertake major geoscientific surveys and disseminate data efficiently												
Egypt	2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
United Republic of Tanzania	2	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Namibia	2	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y
Ethiopia	2	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y
Morocco	2	Y	Y	Y	N	N	Y	Y	T	Y	Y	Y
GSOs with some capacity to undertake major geoscientific surveys and disseminate data												
Cameroon	3	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Nigeria	3	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Equatorial Guinea	3	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y
Botswana	3	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y
Democratic Republic of Congo	3	Y	N	N	Y	Y	N	Y	Y	N	Y	Y
Uganda	3	Y	Y	N	N	N	Y	Y	Y	N	Y	Y
Mozambique	3	Y	Y	N	N	N	N	Y	Y	N	Y	Y
Tunisia	3	Y	Y	N	N	N	N	Y	Y	N	Y	Y
Sudan	3	Y	Y	N	N	Y	N	Y	N	N	Y	N
Zambia	3	Y	Y	N	N	N	N	Y	Y	N	Y	N
Zimbabwe	3	Y	N	N	N	N	N	Y	Y	N	Y	N
GSOs with limited capacity to undertake geoscientific surveying												
Ghana	4	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y
Burkina Faso	4	Y	N	N	Y	N	N	Y	Y	Y	Y	Y
Swaziland	4	Y	N	N	Y	N	N	N	Y	Y	Y	Y
Togo	4	Y	N	N	N	N	N	Y	Y	Y	Y	Y
Chad	4	Y	N	N	N	N	N	N	Y	Y	Y	Y
Mali	4	Y	N	N	N	N	N	Y	Y	Y	N	Y
Senegal	4	Y	Y	N	N	N	N	Y	Y	N	Y	N
Somalia	4	Y	N	N	N	N	Y	Y	N	N	Y	N
Rwanda	4	Y	N	N	N	N	N	N	N	N	Y	Y
Algeria	4	Y	N	N	N	N	N	N	N	N	Y	N

Country	Ranking	Geology	Geophysics	Marine	Hydro-geology	Risk and hazards	Remote sensing	Mapping	Mining	Energy	Publication	Website in English
Madagascar	4	Y	N	N	N	N	N	N	N	N	Y	N
Benin	4	Y	N	N	N	N	N	N	N	N	N	N
Comoros	4	N	N	N	N	N	N	N	N	N	Y	N
Djibouti	4	Y	N	N	N	N	N	N	N	N	N	N
Liberia	4	N	N	N	N	N	N	N	N	N	Y	N
Malawi	4	Y	N	N	N	N	N	N	N	N	N	N
Mauritania	4	N	N	N	N	N	N	N	N	N	Y	N
GSOs for which no geological survey detected, or no information available												
Republic of the Congo	0	N	N	N	N	N	N	N	N	N	N	Y
Sierra Leone	0	N	N	N	N	N	N	N	N	N	N	Y
Angola	0	N	N	N	N	N	N	N	N	N	N	N
Burundi	0	N	N	N	N	N	N	N	N	N	N	N
Cabo Verde	0	N	N	N	N	N	N	N	N	N	N	N
Central African Republic	0	N	N	N	N	N	N	N	N	N	N	N
Côte d'Ivoire	0	N	N	N	N	N	N	N	N	N	N	N
Eritrea	0	N	N	N	N	N	N	N	N	N	N	N
Gabon	0	N	N	N	N	N	N	N	N	N	N	N
Gambia	0	N	N	N	N	N	N	N	N	N	N	N
Guinea	0	N	N	N	N	N	N	N	N	N	N	N
Guinea–Bissau	0	N	N	N	N	N	N	N	N	N	N	N
Kenya	0	N	N	N	N	N	N	N	N	N	N	N
Lesotho	0	N	N	N	N	N	N	N	N	N	N	N
Libya	0	N	N	N	N	N	N	N	N	N	N	N
Mauritius	0	N	N	N	N	N	N	N	N	N	N	N
Niger	0	N	N	N	N	N	N	N	N	N	N	N
Sao Tome and Principe	0	N	N	N	N	N	N	N	N	N	N	N
Seychelles	0	N	N	N	N	N	N	N	N	N	N	N

Annex 5: Fundamental datasets

Table 16: Fundamental datasets identified by African communities

Data Sets	UCT	SADC	RCMRD	RECTAS	ITC
Transportation		x	x	x	x
Administrative boundaries	x	x	x	x	x
Hydrography	x	x	x	x	x
Settlements and population centres	x	x		x	x
Topography and physiography	x	x	x	x	
Elevation and hypsography	x	x		x	x
Vegetation				x	x
Land cover	x	x	x		x
Land use	x	x	x		x
Geodetic control	x	x	x	x	x
Cadastre and tenure		x	x	x	
Imagery	x	x			x
Geographic and place names	x				x
Geology	x	x			x
Demography					x
Property street address					x
Utility networks	x				x
Climate		x			x
Geoid model	x				
Conservation areas	x				x
Forestry reserves	x				
Soil	x				x
Minerals	x				
Ecological zones					x
Land suitability					x
Fauna					x

Source: ECA (2007).

Note: UCT (University of Cape Town), SADC (Southern African Development Community), RCMRD (Regional Centre For Mapping Resource For Development), RECTAS (Regional Centre for Training in Aerospace Surveys), and ICT (Information Technology Center)

Table 17: Weighted scores of survey results from EIS-Africa mailing list

Data sets	Weighted score
Hydrological network (drainage, rivers, water-source)	2.75
Administrative boundaries (districts, provinces, national)	2.5
Climate (rainfall, temperature, solar radiation, and other variables)	1.875
Census (population and housing census)	1.625
Geology	1.5
Soils	1.5
Elevation and terrain derivatives	1.25
Land use	1.25
Population distribution	1.25
Road network	1.25
Agricultural census	1.125
Infrastructure	1.125
Topographic maps	1
Agriculture	0.875
Cadastre	0.625
Important structures, medical, school, among others	0.625
Land cover	0.625
Road, railway and airports	0.625
Transport	0.625
Coastlines	0.625
Economic indicators	0.625
Natural resources	0.625
Ground water resources	0.625
Place names (locality, towns, country)	0.5
Socio-economic indicators	0.5
Demography	0.375
Health demographics	0.375

Source: ECA (2007).

Note: EIS-Africa is the Network for the Cooperative Management of Environmental Information in Africa (see http://www.eis-africa.org/en/about-us).

Annex 6: Assessment of mining information needs and capacities

GSO capacity ratings:

1. Strong capacity to collect and disseminate high quality geoscientific data and information;

2. Capacity to undertake major geoscientific surveys and disseminate data efficiently;

3. Some capacity to undertake major geoscientific surveys and to disseminate data;

4. Limited capacity to undertake geoscientific surveying; and

0. No geological survey detected, or no information available.

Table 18: Mining, quarrying and petroleum as a percentage of GDP data for African countries along with the Geoscience Australia assessment of GSO capacities

Country	GSO Capacity	Latest year with data	Percentage of economy	First year with data (1970-)	Percentage of economy	Maximum year	Maximum percentage of economy	Minimum year	Minimum percentage of economy	Number of years with data	Percentage of years with data
Libya	0	2007	74.28	1970	61.26	2006	76.92	2001	34.19	23	60.53
Congo	0	2010	65.54	1970	1.26	2006	68.61	1970	1.26	32	78.05
Gabon	0	2010	59.32	1972	32.44	2010	59.32	1988	21.50	28	71.79
Angola	0	2010	45.77	1985	28.28	2006	58.22	1986	17.84	11	42.31
Chad	4	2008	45.61	1975	0.81	2006	45.99	1993	0.14	19	55.88
Algeria	4	2003	36.54	1970	13.90	2000	40.36	1971	9.83	34	100.00
Botswana	3	2010	31.27	1972	10.92	1989	51.16	1975	8.14	38	97.44
Nigeria	3	2009	28.28	1970	9.62	2000	46.45	1970	9.62	40	100.00
Guinea	0	2010	19.49	1990	19.07	2010	19.49	1998	12.49	21	100.00
Mauritania	4	2009	19.36	1970	24.80	2006	29.73	1988	6.89	40	100.00
Egypt	2	2010	13.75	1970	2.13	1980	16.14	1972	0.96	33	80.49
Namibia	2	2009	9.95	1980	37.41	1980	37.41	2003	8.02	30	100.00
Zimbabwe	3	2010	9.64	1970	6.58	2005	29.03	2001	0.92	41	100.00
Sudan	3	2010	9.30	1970	0.24	2008	17.31	1983	0.05	34	82.93
Democratic Republic of the Congo	3	1977	8.81	1970	22.18	1970	22.18	1977	8.81	8	100.00
Réunion	-	1992	8.71	1970	8.94	1973	10.56	1984	7.15	22	95.65
South Africa	1	2010	8.53	1970	8.23	1980	19.36	1997	5.91	41	100.00
Lesotho	0	2010	7.03	1970	1.24	2008	8.53	1998	0.09	41	100.00
Cameroon	3	2010	6.64	1970	0.65	1984	16.40	1971	0.22	39	95.12
Tunisia	3	2009	6.22	1970	5.39	1981	12.35	1995	2.67	40	100.00
Mali	4	2010	6.17	1982	1.41	2002	10.74	1989	1.07	26	89.66
Niger	0	2010	5.87	1975	5.90	1979	14.23	2003	1.92	36	100.00
Zambia	3	2010	4.37	1970	29.37	1974	31.78	2009	2.60	39	95.12
Sierra Leone	0	2010	4.07	1970	16.62	1985	17.54	2001	1.72	31	75.61
Morocco	2	2010	3.87	1970	3.30	1974	12.61	2004	1.61	41	100.00
United Republic of Tanzania	2	2010	3.32	1970	1.14	2007	3.55	1985	0.30	41	100.00
Cabo Verde	0	2007	3.05	1980	0.64	2006	3.12	1982	0.45	28	100.00

Country	GSO Capacity	Latest year with data	Percentage of economy	First year with data (1970-)	Percentage of economy	Maximum year	Maximum percentage of economy	Minimum year	Minimum percentage of economy	Number of years with data	Percentage of years with data
Burkina Faso	4	2009	2.76	1970	0.07	2009	2.76	1981	0.01	36	90.00
Togo	4	2010	2.56	1970	5.04	1974	22.02	2010	2.56	25	60.98
Ghana	4	2010	2.20	1970	1.65	1994	5.64	1982	0.33	35	85.37
Senegal	4	2010	1.94	1970	17.62	1974	20.93	1982	0.20	41	100.00
Central African Republic	0	2010	1.83	1970	4.14	1993	5.66	2008	1.56	32	78.05
Mozambique	3	2010	1.41	1991	0.17	2007	1.43	1999	0.13	20	100.00
Malawi	4	2007	1.14	1970	0.15	2001	1.46	1972	0.11	14	36.84
Gambia	0	2010	1.01	1970	0.32	2004	1.54	1989	0.02	40	97.56
Sao Tome and Principe	0	2007	0.72	1974	0.28	2007	0.72	1980	0.25	13	38.24
Kenya	0	2010	0.69	1970	0.35	2008	0.71	1995	0.15	41	100.00
Rwanda	4	2010	0.65	1970	2.18	1977	2.62	1994	0.02	41	100.00
Ethiopia	2	2010	0.65	1970	0.21	2010	0.65	1987	0.08	37	90.24
Burundi	0	2008	0.62	1970	0.30	1989	1.13	1977	0.24	25	64.10
Liberia	4	2010	0.57	1970	28.35	1975	38.02	1999	0.00	35	85.37
Uganda	3	2010	0.31	1970	1.06	1970	1.06	1988	0.09	32	78.05
Somalia	4	1987	0.30	1970	1.02	1971	1.05	1980	0.25	18	100.00
Côte d'Ivoire	0	2000	0.28	1970	0.23	1984	2.81	1976	0.15	29	93.55
Swaziland	4	2010	0.26	1970	10.81	1970	10.81	2008	0.21	32	78.05
Benin	4	2010	0.23	1970	8.51	1971	8.82	1982	0.17	37	90.24
Madagascar	4	2010	0.23	1970	18.44	1973	19.76	1999	0.10	32	78.05
Djibouti	4	1998	0.18	1990	0.14	1991	0.19	1994	0.11	9	100.00
Mauritius	0	2010	0.04	1970	0.09	1996	0.18	2007	0.03	41	100.00
Guinea-Bissau	0	2010	0.01	1986	0.07	1991	8.49	2010	0.01	14	56.00
Seychelles	0	1984	0.00	1976	0.16	1978	0.18	1984	0.00	9	100.00

Source: United Nations Statistics Division (2013), Kay and others (2012).

Annex 7: Assessment of energy related information needs and capacities

GSO capacity ratings:

1. Strong capacity to collect and disseminate high quality geoscientific data and information;

2. Capacity to undertake major geoscientific surveys and disseminate data efficiently;

3. Some capacity to undertake major geoscientific surveys and to disseminate data;

4. Limited capacity to undertake geoscientific surveying;

0. No geological survey detected, or no information available.

Table 19: Petroleum reserves, geothermal energy potential and hydro-electricity potential relative to information available from national GSOs

	GSO	Petroleum						Geothermal				Hydro-electricity					
	Overall capacity	Crude oil reserves (million barrels)	Natural gas reserves (million barrels oil equivalent)	Total petroleum reserves (million barrels of oil equivalent)	Existing petroleum industry	Energy information available	Information rating (0-1)	Potential / Production	Energy	Hydrology	Rating (0-2)	Anticipated total hydro-electricity capacity (MW)	Hydrology	Hazards	Geology	Mapping	Rating (0-4)
Algeria	4	12,200	29,700	41,900	Y	N	0		N	N	0	278	N	N	Y	N	1
Angola	0	9,055		9,055	Y	N	0		N	N	0	1954	N	N	N	N	0
Benin	4				N	N	0		N	N	0	251	N	N	Y	N	1
Botswana	3				N	Y	1		Y	Y	2	0	Y	N	Y	Y	3
Burkina Faso	4				N	Y	1		Y	Y	2	107	Y	N	Y	Y	3
Burundi	0				N	N	0	Potential	N	N	0	227	N	N	N	N	0
Cameroon	3				Y	Y	1		Y	Y	2	2548	Y	Y	Y	Y	4
Cabo Verde	0				N	N	0		N	N	0	0	N	N	N	N	0
Central African Republic	0				N	N	0		N	N	0	49	N	N	N	N	0
Chad	4				Y	Y	1		Y	N	1	6	N	N	Y	N	1
Comoros	4				N	N	0	Potential	N	N	0	1	N	N	N	N	0
Côte d'Ivoire	0				Y	N	0		N	N	0	883	N	N	N	N	0
Democratic Republic of Congo	3				Y	N	0	Potential	N	Y	1	6100	Y	Y	Y	Y	4
Djibouti	4				N	N	0	Potential	N	N	0	0	N	N	Y	N	1
Egypt	2	4,400	13,200	17,600	Y	Y	1		Y	Y	2	2890	Y	Y	Y	Y	4
Equatorial Guinea	3				Y	Y	1		Y	N	1	1	N	N	Y	Y	2
Eritrea	0				N	N	0	Potential	N	N	0	0	N	N	N	N	0
Ethiopia	2				N	Y	1	Production	Y	Y	2	4839	Y	N	Y	Y	3
Gabon	0	2,000		2,000	Y	N	0		N	N	0	170	N	N	N	N	0
Gambia	0				N	N	0		N	N	0	0	N	N	N	N	0
Ghana	4				Y	Y	1		Y	Y	2	1705	Y	Y	Y	Y	4
Guinea	0				N	N	0		N	N	0	363	N	N	N	N	0
Guinea–Bissau	0				N	N	0		N	N	0	0	N	N	N	N	0
Kenya	0				N	N	0	Production	N	N	0	907	N	N	N	N	0
Lesotho	0				N	N	0		N	N	0	102	N	N	N	N	0
Liberia	4				N	N	0		N	N	0	100	N	N	N	N	0

	GSO	Petroleum						Geothermal				Hydro-electricity					
	Overall capacity	Crude oil reserves (million barrels)	Natural gas reserves (million barrels oil equivalent)	Total petroleum reserves (million barrels of oil equivalent)	Existing petroleum industry	Energy information available	Information rating (0-1)	Potential / Production	Energy	Hydrology	Rating (0-2)	Anticipated total hydro-electricity capacity (MW)	Hydrology	Hazards	Geology	Mapping	Rating (0-4)
Libya	0	48,472	9,900	58,372	Y	N	0		N	N	0	0	N	N	N	N	0
Madagascar	4				N	N	0		N	N	0	282	N	N	Y	N	1
Malawi	4				N	N	0		N	N	0	729	N	N	Y	N	1
Mali	4				N	Y	1		Y	N	1	255	N	N	Y	Y	2
Mauritania	4				Y	N	0		N	N	0	30	N	N	N	N	0
Mauritius	0				N	N	0		N	N	0	59	N	N	N	N	0
Morocco	2				Y	Y	1		Y	N	1	1349	N	N	Y	Y	2
Mozambique	3				N	N	0		N	N	0	5049	N	N	Y	Y	2
Namibia	2				N	Y	1		Y	N	1	657	N	Y	Y	Y	3
Niger	0				N	N	0		N	N	0	125	N	N	N	N	0
Nigeria	3	37,139	34,320	71,459	Y	Y	1		Y	Y	2	2888	Y	Y	Y	Y	4
Republic of the Congo	0				Y	N	0		N	N	0	899	N	N	N	N	0
Rwanda	4				Y	N	0	Potential	N	N	0	175	N	N	Y	N	1
Sao Tome and Principe	0				N	N	0		N	N	0	32	N	N	N	N	0
Senegal	4				N	N	0		N	N	0	189	N	N	Y	Y	2
Seychelles	0				N	N	0		N	N	0	0	N	N	N	N	0
Sierra Leone	0				N	N	0		N	N	0	89	N	N	N	N	0
Somalia	4				N	N	0		N	N	0	0	N	N	Y	Y	2
South Africa	1				Y	Y	1		Y	Y	2	807	Y	Y	Y	Y	4
Sudan	3	6,700		6,700	Y	N	0		N	N	0	2575	N	Y	Y	Y	3
Swaziland	4				N	Y	1		Y	Y	2	80	Y	N	Y	N	2
Togo	4				N	Y	1		Y	N	1	66	N	N	Y	Y	2
Tunisia	3				Y	N	0		N	N	0	90	N	N	Y	Y	2
Uganda	3				N	N	0	Potential	N	N	0	1396	N	N	Y	Y	2
United Republic of Tanzania	2				N	Y	1	Potential	Y	Y	2	2429	Y	Y	Y	Y	4
Zambia	3				N	N	0	Potential	N	N	0	2813	N	N	Y	Y	2
Zimbabwe	3				N	N	0		N	N	0	1154	N	N	Y	Y	2

Annex 8: Assessment of hydrogeological information needs and capacities

Table 20: Data on renewable groundwater resources, freshwater withdrawals and total renewable water resources per capita, which are used to indicate levels of hydrological information needs for African countries

Country	Overall groundwater information need rank	Hydrogeology related information availability indicator (0-1)	Hydrogeological information available online	Renewable groundwater resources as a percentage of total actual renewable water resources (2011)	Rank	Freshwater withdrawal as percentage of total actual renewable water resources (1999-2005)	Rank	Total renewable water resources per capita (actual) (m3/inhab/yr) (2011)	Rank
Libya	1	0	N	85.71	1	615.40	1	109	1
Tunisia	2	0.3	N	34.71	18	61.74	3	433.7	4
Burkina Faso	3	0.8	Y	76.00	3	5.73	19	736.7	7
Cabo Verde	4	0	N	41.33	11	6.77	16	598.8	5
Morocco	5	0.4	N	34.48	19	43.45	5	898.6	10
Algeria	6	0.1	N	13.00	38	48.89	4	324.3	2
Rwanda	7	0.1	N	73.68	4	1.58	32	868.1	9
Burundi	8	0	N	59.57	5	2.30	26	1462	17
Mauritius	9	0	N	32.46	21	26.35	7	2105	25
Somalia	10	0.3	N	22.45	26	22.44	10	1538	18
Zimbabwe	11	0.2	N	30.00	24	21.02	11	1568	19
Egypt	12	1	Y	2.27	51	96.56	2	694.2	6
Comoros	13	0	N	83.33	2	0.83	37	1592	20
South Africa	14	1	Y	9.34	42	24.28	8	1019	11
Ghana	15	0.9	Y	49.44	6	1.85	29	2131	26
Kenya	16	0	N	11.40	40	8.91	14	737.8	8
Sudan and South Sudan	17	0.3	N	10.85	41	42.78	6	1445	16
Malawi	18	0.1	N	14.47	36	7.85	15	1123	12
United Republic of Tanzania	19	1	Y	31.16	22	5.39	21	2083	23
Nigeria	20	0.9	Y	30.40	23	4.58	23	1762	21
Côte d’Ivoire	21	0	N	46.64	7	1.91	28	4026	33
Eritrea	22	0	N	7.94	44	9.24	13	1163	13
Djibouti	23	0.1	N	5.00	49	6.27	18	331.1	3
Ethiopia	24	0.9	Y	16.39	31	4.56	24	1440	15
Uganda	25	0.4	N	43.94	10	0.48	40	1913	22

Country	Overall groundwater information need rank	Hydrogeology related information availability indicator (0-1)	Hydrogeological information available online	Renewable groundwater resources as a percentage of total actual renewable water resources (2011)	Rank	Freshwater withdrawal as percentage of total actual renewable water resources (1999-2005)	Rank	Total renewable water resources per capita (actual) (m3/inhab/yr) (2011)	Rank
Swaziland	26	0.7	Y	14.63	35	23.10	9	3749	32
Togo	27	0.2	N	38.78	14	1.15	35	2388	27
Lesotho	28	0	N	16.55	30	1.45	34	1377	14
Mali	29	0.2	N	20.00	27	6.55	17	6313	36
Zambia	30	0.3	N	44.68	9	1.49	33	7807	39
Chad	31	0.1	N	26.74	25	2.05	27	3731	31
Angola	32	0	N	39.19	12	0.48	41	7544	37
Guinea-Bissau	33	0	N	45.16	8	0.56	38	20039	45
Mauritania	34	0	N	2.63	50	11.84	12	3219	30
Senegal	35	0.3	N	9.02	43	5.72	20	3039	29
Niger	36	0	N	7.43	46	2.92	25	2094	24
Madagascar	37	0.1	N	16.32	32	4.90	22	15810	43
Cameroon	38	1	Y	35.03	17	0.34	43	14254	42
Botswana	39	0.9	Y	13.89	37	1.59	31	6027	35
Namibia	40	0.4	N	11.85	39	1.62	30	7625	38
Equatorial Guinea	41	0.4	N	38.46	15	0.07	47	36111	49
Central African Republic	42	0	N	38.78	13	0.05	50	32182	48
Gabon	43	0	N	37.80	16	0.08	46	106910	51
Democratic Republic of the Congo	44	0.8	Y	32.81	20	0.05	49	18935	44
Benin	45	0.1	N	6.82	47	0.49	39	2900	28
Gambia	46	0	N	6.25	48	1.13	36	4505	34
Guinea	47	0	N	16.81	29	0.24	44	22109	46
Sierra Leone	48	0	N	15.63	33	0.13	45	26680	47
Liberia	49	0	N	19.40	28	0.06	48	56188	50
Mozambique	50	0.3	N	7.83	45	0.41	42	9072	40
Congo	51	0	N	14.66	34	0.01	51	200966	52
Sao Tome and Principe	52	0	N	0.00	52	0.00	53	12899	41
Seychelles	53	0	N	0.00	53	0.00	52	0	53

Source: FAO AQUASTAT (2013), Kay and others (2012).

Annex 9: Assessment of hazard related information needs and capacities

Table 21: Number of geological hazards (excluding flooding) including the number of people killed and affected, and the availability information from GSOs related to these hazards

Country	Number of Events	Number of people killed	Total number of people affected	Indicator of GSO hazards information availability	Risks and hazards information available
Algeria	21	6,774	1,367,898	0.1	N
Comoros	6	19	309,200	0	N
Democratic Republic of the Congo	10	603	193,749	0.9	Y
Somalia	1	298	105,083	0.3	N
Egypt	7	726	93,993	1	Y
Uganda	9	548	77,103	0.3	N
Malawi	3	13	70,836	0.1	N
Morocco	5	12,760	50,681	0.3	N
Guinea	1	275	21,436	0	N
Cameroon	4	1,803	13,547	1	Y
Ethiopia	13	132	11,779	0.2	N
Rwanda	5	126	10,223	0.1	N
United Republic of Tanzania	11	32	9,141	1	Y
Sudan	2	3	8,015	0.9	Y
Cabo Verde	1	0	6,306	0	N
Seychelles	1	3	4,830	0	N
Mozambique	2	91	3,976	0.2	N
Republic of the Congo	2	160	2,173	0	N
Nigeria	3	32	1,800	0.9	Y
South Africa	9	104	1,448	1	Y
Liberia	1	46	200	0	N
Zambia	1	9	150	0.2	N
Burundi	1	3	120	0	N
Kenya	6	57	26	0	N
Sierra Leone	1	16	5	0	N
Angola	1	13	0	0	N
Benin	0	0	0	0.1	N
Botswana	0	0	0	0.2	N
Burkina Faso	0	0	0	0.2	N
Central African Republic	0	0	0	0	N
Chad	0	0	0	0.1	N
Côte d'Ivoire	0	0	0	0	N
Djibouti	0	0	0	0.1	N
Equatorial Guinea	0	0	0	0.3	N
Eritrea	0	0	0	0	N
Gabon	0	0	0	0	N
Gambia	0	0	0	0	N
Ghana	1	17	0	0.9	Y
Guinea–Bissau	0	0	0	0	N
Lesotho	0	0	0	0	N
Libya	1	320	0	0	N

Country	Number of Events	Number of people killed	Total number of people affected	Indicator of GSO hazards information availability	Risks and hazards information available
Madagascar	0	0	0	0.1	N
Mali	0	0	0	0.2	N
Mauritania	0	0	0	0	N
Mauritius	0	0	0	0	N
Namibia	0	0	0	1	Y
Niger	0	0	0	0	N
Sao Tome and Principe	0	0	0	0	N
Senegal	0	0	0	0.2	N
Swaziland	0	0	0	0.1	N
Togo	0	0	0	0.2	N
Tunisia	1	13	0	0.2	N
Zimbabwe	0	0	0	0.2	N

Source: Emergency Events Database (2013), Kay and others (2012).

Annex 10: Effectiveness of geological support

GSO capacity ratings:

1. Strong capacity to collect and disseminate high quality geoscientific data and information;

2. Capacity to undertake major geoscientific surveys and disseminate data efficiently;

3. Some capacity to undertake major geoscientific surveys and to disseminate data;

4. Limited capacity to undertake geoscientific surveying; and

0. No geological survey detected, or no information available.

Collaborative project ratings:

1. Major

2. Substantial

3. Significant

4. Minor

0. None

Table 22: Geological support provided to countries along with their capacity and minerals potential

Country	World Bank funding (0 = none, 1 = some)	Collaborative project rating	GSO capacity	Minerals potential
Algeria	0	4	4	3
Angola	1	3	0	3
Benin	0	0	4	0
Botswana	1	2	3	1
Burkina Faso	1	0	4	1
Burundi	1	0	0	1
Cameroon	1	3	3	3
Cabo Verde	1	0	0	0
Central African Republic	1	0	0	1
Chad	0	3	4	3
Comoros	0	0	4	0
Congo	1	0	0	3
Côte d'Ivoire	1	0	0	3
Democratic Republic of the Congo	1	0	3	1
Djibouti	1	3	4	0
Egypt	1	2	2	1
Equatorial Guinea	0	0	3	3
Eritrea	0	3	0	3
Ethiopia	1	3	2	1
Gabon	0	3	0	3
Gambia	1	3	0	3
Ghana	1	2	4	3
Guinea	1	4	0	3
Guinea–Bissau	1	0	0	0
Kenya	1	2	0	3
Lesotho	1	3	0	3
Liberia	1	0	4	3
Libya	0	3	0	0
Madagascar	1	3	4	1
Malawi	1	2	4	3
Mali	1	2	4	3
Mauritania	1	3	4	3
Mauritius	1	3	0	0
Morocco	1	1	2	1
Mozambique	1	2	3	1
Namibia	0	2	2	1
Niger	1	2	0	1
Nigeria	1	2	3	3
Rwanda	1	0	4	3
Sao Tome and Principe	1	2	0	0
Senegal	1	3	4	3
Seychelles	0	3	0	0
Sierra Leone	1	3	0	1

Country	World Bank funding (0 = none, 1 = some)	Collaborative project rating	GSO capacity	Minerals potential
Somalia	0	3	4	0
South Africa	1	2	1	1
Sudan	0	3	3	3
Swaziland	0	3	4	3
United Republic of Tanzania	1	2	2	1
Togo	1	3	4	1
Tunisia	1	3	3	3
Uganda	1	2	3	3
Zambia	1	1	3	1
Zimbabwe	1	1	3	1

Source: Kay and others (2012).