The potential for diamonds in Liberia
Liberia—an under-explored West African diamond region:

- More than 160 known occurrences of kimberlite, with many part of a single province that includes diamondiferous kimberlites in neighbouring Sierra Leone and Guinea.
- A long history of alluvial diamond production in western and central Liberia.
- Potential for new alluvial and bedrock diamond discoveries in under-explored Archean terrane.

Diamonds in West Africa

Diamonds in West Africa are produced from both primary (bedrock) kimberlite sources and secondary (alluvial) placers in Ghana, Guinea, Sierra Leone, Togo and Liberia. West African diamonds account for approximately one per cent of the global production of diamonds (BGS, 2015).

The Man Shield, that underlies a large part of central and western Liberia, is an area of thick (>300 kilometres), Archean crust with low geothermal heat flow (c. 40 mW/m²), representing a favourable tectonic environment for economic kimberlites (Kjarsgaard, 2007). It is host to numerous kimberlite pipes and dykes, some of which are known to be diamondiferous. Published information about West African kimberlites is generally sparse, with those in Sierra Leone being the most studied. West African kimberlites can be
broadly divided into two groups according to their age:

1. Precambrian kimberlites of Paleoproterozoic (2.1–2.3 Ga), Mesoproterozoic (1.15 Ga) and Neoproterozoic (700 Ma) age and
2. Mesozoic kimberlites of late Jurassic (150 Ma) to late Cretaceous (80 Ma) age.

Notable Jurassic-age kimberlite deposits in the region include the Tongo kimberlite (Sierra Leone) that has an estimated resource of about 1 million carats, and the Baoulé kimberlite mine (Guinea), with an estimated resource in excess of 3 million carats.

Diamond-bearing alluvial placers are frequently associated with kimberlite-rich areas in West Africa, although in many cases their age, formation and distribution are not clearly understood. Both industrial and gem-quality diamonds of varying size have been recovered from alluvial placers across the region. A small number of alluvial deposits have been successfully mechanised (e.g. Mandala, Guinea), although most are worked on a small scale by artisanal miners. In Sierra Leone, the diamond-producing areas are concentrated in Kono, Kenema and Bo Districts and are mainly situated in the drainage areas of the Sewa, Bafi, Woa, Mano and Moa Rivers. According to official figures, Sierra Leone exported about 633,000 carats in 2013 (Kimberley Process, 2015). In Guinea, JORC-compliant inferred resources of 2.5 million carats at Droujba and 2.9 million carats at Katcha have been reported.

In Liberia, diamonds are produced solely from alluvial placers by artisanal miners located in the west and central parts of the country. Liberia has a long history of alluvial diamond production, with an output of about 14 million carats during the last 50 years. Output from small-scale operations peaked at about 600,000 carats per annum during the early part of the 1970s. Historic diamond production was tarnished by its association with conflict in the region. For this reason diamond production between 2002 and 2007 was depressed by export sanctions imposed by the United Nations, in an attempt to end illicit diamond mining in Liberia. In 2007 Liberia became a Kimberley Process participant and, since then, diamond production has steadily risen to approximately 80,000 carats in 2014 (Central Bank of Liberia, 2014). Reporting of diamond production is compulsory under the Kimberley Process; however, production figures are not guaranteed to represent the entire production of diamonds in country due to the artisanal nature of the mining. Exports and imports of rough diamond are overseen by the Government Diamond Office (GDO) within the Ministry of Lands, Mines and Energy and by the Bureau of Customs.

The geology of Liberia

Liberia is underlain by the Man Shield, part of the West African Craton, which comprises two major areas of Archean and Paleoproterozoic rocks, mapped during the 1970s in a joint programme between the Liberia Geological Survey (LGS) and the United States Geological Survey (USGS).

The Precambrian Man Shield underlying Liberia can be subdivided into three age provinces (see map). The Liberian age province (2.5–3.0 Ga) extends across central and western Liberia and is composed of a suite of granitoid gneisses and migmatites which are infolded with supracrustal metavolcanic and metasedimentary rocks and intruded by a younger igneous complex. The Eburnean age province (1.9–2.3 Ga) of southern and eastern Liberia consists of tightly folded paragneiss, migmatite and amphibolite. It is separated from the Liberian age province by the north-east-trending Cestos Shear Zone. Rocks of the Pan African-age province (c. 550 Ma) underlie an elongate, fault-bounded zone along much of Liberia’s coastline. They comprise metasedimentary and mafic meta-igneous rocks containing granitic bodies and subordinate norite intrusions.

Mesozoic rocks in Liberia include extensive north-west-trending dolerite dykes emplaced during a period of rift-related magmatism (180–200 Ma). Reactivation of north-east-trending Archean basement structures, and the subsequent emplacement of kimberlites, occurred during a later period of rifting (90–140 Ma). Diamond-bearing kimberlites are restricted to the Liberian age province. Both the Eburnean and Pan African-age provinces were thought to be barren (Haggerty, 1992). However, recent discoveries of alluvial diamonds in south-eastern Liberia cast doubt on this assumption and highlight some uncertainty in the understanding of the tectonic evolution of the region.

The USGS/LGS documented about 160 kimberlite occurrences in central and western Liberia. However, due to lack of bedrock exposure, poor
access and dense vegetation, this may not be an accurate reflection of the true number of occurrences.

**Diamond exploration**

Liberia has a lengthy history of diamond exploration, particularly in central and western Liberia. Between 1962 and 1966 the Diamond Mining Company (Liberia) identified a number of kimberlite dykes as part of a regional exploration programme. In 1972 the United Nations undertook a mineral indicator survey over western Liberia and discovered the small Mano Godua kimberlite pipe. In the late 1970s a number of companies were active along the Lofa River and Yambasi creek. Many of the early exploration campaigns concentrated on the discovery of alluvial diamond deposits. However, seasonal flooding, poor access and the erratic distribution of diamond-bearing gravels meant that many companies were ultimately unsuccessful in bringing Liberian alluvial diamond deposits into commercial production. Nevertheless, the discovery of alluvial diamonds alerted companies to the possibility of discovering buried kimberlites in central and western Liberia.

Since the 1980s, exploration for diamond-bearing kimberlites has increased significantly leading to the recent discovery of diamond-bearing kimberlites in western Liberia. Three distinct clusters have been recognised: Kumgbor, Mano Godua and Weasua. Other kimberlite occurrences, identified by the USGS and LGS, are found in Nimba County, central Liberia. Seven new discoveries were made by Mano River Resources, near Weasua, between 2000 and 2006. In addition a series of kimberlite dykes, and a single pipe, were discovered in the Camp Alpha area by the Youssef Diamond Mining Company (YDMC) in 2013 (Haggerty, 2015). All of the Liberian occurrences are small pipes (with surface areas less than 0.1 km²) and thin dykes (up to a few metres thick) (Thorman, 2006).

To date, Liberian kimberlites have not been commercially exploited for diamonds and the number of kimberlites with economic potential remains unknown. The recent increase in diamond production is linked to a rise in the number of alluvial diamond deposits being worked and the increased mechanisation of the production process. No modern estimates of diamond resources have been published for Liberia.

**Diamonds in Liberia — key areas**

USGS and LGS regional surveys during the mid 1970s identified numerous alluvial placers and kimberlite indicator minerals in central and western Liberia. On the basis of these surveys, together with previous exploration and small-scale mining activity, extensive areas in central and western Liberia with significant alluvial diamond deposits have been defined. Another locality in south-eastern Liberia has recently been identified as an artisanal diamond mining area.

**Lofa River**

The Lofa River is one of the largest rivers in the country draining a distance of about 350 kilometres from the east of the Wologizi Range. The Lofa River region, especially from Weasua to the coast, is host to significant alluvial diamond production, with numerous workings in the Lofa and Yambasi River basins and associated tributaries. Occurrences in these basins extend from Weasua to the coast at Bomboja. The distribution of diamonds in alluvial deposits in the Lofa River area is highly erratic, although early exploration reports suggest that lower terrace gravels, ancient alluvial river flats and deep-plunge pools within the active river channel are the most prospective areas for diamond recovery. The high diamond potential of the Lofa River area is attributed to a number of factors, including the known occurrence of kimberlitic source rocks and close proximity to the highly prospective eastern diamond region in Sierra Leone (Dorbor, 2010).

**Mano, Kumgbor and Morro-Gbeya rivers**

The Kumgbor and Morro-Gbeya Rivers, which drain into the Mano River, are areas of intense
artisanal mining, with diamonds produced from many of the creeks, particularly the Papaya Creek (Dorbor, 2010). Gem-quality diamonds, up to a maximum of 170 carats, and industrial diamonds were recovered from this area in the late 1970s.

**Du River**

Historic alluvial workings have been identified in the Kakata area of the Du River basin. The diamonds recovered from this area are generally small but mostly of gem quality. Kimberlitic rocks and associated minerals have not been found in the Du River diamond area and, therefore, the source of the alluvial diamonds remains unknown, although it has been suggested that local conglomerates may be a potential source (Dorbor, 2010).

**Yaa River, Boe and Nzar creeks**

The Gbapa-Bahn diamond area in Nimba County is relatively under-explored. It is largely confined to the margins of the Boe Creek, where kimberlitic rocks were identified by the USGS and LGS in the early 1970s. The area has a history of small-scale alluvial diamond mining dating back to the 1950s. The diamonds are typically found in floodplain and river-terrace gravels flanking Bee Creek, although little is known about their distribution, morphology and grade. However, local reports suggest that diamonds up to 15 carats have been recovered from the area (Dorbor, 2010).

**Sinoe River**

Alluvial diamond workings are found in the area around the Sinoe River in south-eastern Liberia, but no information about these operations is available (Dorbor, 2010). However, this is the first evidence of diamond occurrences in this part of the country, generally thought to be underlain by Proterozoic rocks of Eburnean age, which are considered to be barren. This highlights possible uncertainty over the tectonic evolution of this part of the country and the extent of the Archean outcrop in Liberia (Haggerty, 1992).

**Kimberlite-hosted diamond deposits**

The majority of Man Shield kimberlites are geochemically classified as type-A, non-micaceous kimberlites (i.e. on-craton, basaltic kimberlites) and typically occur as small pipes and abundant dykes. Liberian kimberlites occur in

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**Diagram:**

Principal diamond occurrences in western Liberia.
three distinct clusters, two of which are Jurassic in age (Kumgbor and Mano Godua) and one older, Neoproterozoic-age, cluster (Weasua) (Skinner et al., 2004). The Jurassic kimberlites are thought to form part of single kimberlite province that extends into neighbouring Sierra Leone and Guinea. Further evidence for the existence of a single kimberlite province is given by Taylor et al. (1994) who suggest, on geochemical grounds, that Jurassic kimberlites from Liberia, Sierra Leone and Guinea are all type-A, non-micaceous kimberlites.

The recent discovery of a kimberlite pipe (2.5 hectares in area) in the Camp Alpha region in Kumgbor (Haggerty, 2015) highlights the potential for bedrock-hosted diamonds in Liberia. The associated dykes have significant micro-diamond populations, suggesting that the pipe may have economic potential.

**Kimberlite indicator minerals**

The identification of resistant kimberlite indicator minerals (KIMs), such as garnet, spinel, ilmenite, clinopyroxene, forsterite, orthopyroxene and zircon, in stream sediments and soil samples is a well-established exploration tool for kimberlites (Kjarsgaard, 2007). A number of these minerals have been widely identified in stream sediments in Liberia. To date, indicator minerals have only been analysed from a small number of kimberlites in Liberia. For example, the composition of garnet (a chromium-rich, calcium-poor variety) and spinel (a chromium- and magnesium-rich variety) from the Neoproterozoic Weasua kimberlites suggest that these pipes may be prospective for diamonds (Skinner et al., 2004). Similarly, the chemistry of large ilmenite crystals recovered from kimberlites at Camp Alpha in Liberia (Haggerty, 2015) and from Koidu in Sierra Leone (Tomkins and Haggerty, 1984) suggests that these kimberlites are highly prospective for diamonds. The presence of micro-diamonds in a kimberlite is another strong indicator of the macro-diamond potential of a kimberlite; the significant population of micro-diamonds recovered from kimberlites at Camp Alpha in Liberia is, therefore, encouraging.

Comparative studies of kimberlites in eastern Sierra Leone and western Liberia focussed on the KIM piemoltenite. This research identified kimberlites in Sierra Leone trending east–west. These lack a distinct magnetic anomaly as do north–south trending kimberlites in Liberia. Similar east–west trending kimberlites with no clear magnetic signature may be present in Liberia (Haggerty, 1978).

**Geobotany**

Localised swampy conditions are a possible guide to the presence of kimberlites. This is due to the clay-rich and hence impervious nature of the kimberlite bedrock. Furthermore it has been suggested that, a new species of palm, Pandanus candelabrum, may be restricted to the soils developed over kimberlite pipes but not kimberlite dykes (Haggerty, 2015), possibly diagnostic of coarsely-brecciated kimberlite pipe eluvium. If this relationship is substantiated, it has potentially important implications for improving future exploration for kimberlite pipes in Liberia and across West Africa.

**Potential for new discoveries**

On the basis of favourable basement geology, the wide occurrence of alluvial diamonds and the known presence of kimberlites, there is considered to be significant potential for the discovery of additional diamond resources, both in bedrock and alluvium. The abundance of hypabyssal-(root-zone) kimberlites relative to diatreme-facies kimberlites in the Man Shield is indicative of extensive erosion across the region.

River systems in western Liberia are strongly influenced by the underlying geology and structures. The river courses are irregular, commonly leading to sporadic sedimentation. In the case of the Lofa River this results in low overall volumes of gravel deposition but produces small pockets of gravel rich in heavy
minerals (Leuria, 1966). Terraces along the river are frequently the site of reorientation of heavy minerals, although these are generally difficult to identify as they are blanketed by thick lateritic overburden. Geomorphological mapping in the Koidu area of Sierra Leone, the Birim area of Ghana and the Tortiya area of Coté d’Ivoire highlight the benefits of modern paleogeomorphic studies for diamond exploration. This research emphasises the importance of understanding the Quaternary evolution and hence the depositional environments in the region and the influence that this has had on local diamond distribution. A similar approach could help to delineate the most prospective areas for alluvial diamond exploration in west and central Liberia.

The potential for offshore diamonds along the Liberian coastline is high. Although studies have suggested that the greatest quantity of diamonds is located proximal to the source, such as at Koidu, Sierra Leone, where there has been extensive erosion, such as in Liberia, the potential for distal transport should not be overlooked. The estuary of the Lofa River at Bomboja is considered to be a favourable target for the development of placer diamond deposits offshore. Attempts to begin mining in this area without the prerequisite exploration phase have not been successful.

Historic diamond production in Liberia has been sporadic and has used primitive recovery techniques. Large areas of prospective ground have not been evaluated using modern methods. Ground-based electromagnetic and magnetic surveys, successfully employed in Sierra Leone and Guinea, should also be employed in conjunction with botanical surveys and KIM-chemistry.

Selected references


Leuria, B. 1966. Notes on the geology of the Lofa River couth of Weasua, with a comment on diamond dispersal and recovery. Diamond Mining Corporation of Liberia, Ltd.


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