Overview of Diamond Resources in Africa

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From the discovery of diamonds in South Africa in 1866 until the end of 2013, Africa is estimated to have produced almost 3.2 Bct out of a total global production of 5.03 Bct, or 63.6% of all diamonds that have ever been mined. In 2013 African countries ranked 2nd (Botswana), 3rd (DRC), 6th (Zimbabwe), 7th (Angola), 8th (South Africa), and 9th (Namibia), in terms of carat production and 1st (Botswana), 4th (Namibia), 5th (Angola), 6th (South Africa), 7th (Zimbabwe), and 9th (DRC), in terms of value of the diamonds produced. In 2013 Africa produced 70.6 Mct out of a global total of 130.5 Mct or 54.1%, which was valued at US$ 8.7 billion representing 61.5% of the global value of US$ 14.1 billion.

Introduction

It is difficult to do justice to the vast quantity of diamonds produced and the variety of diamond resources in Africa, in a single article. In order to present the various African deposits logically, a Tier structure is used for primary (kimberlite) deposits as follows: Tier-1 (World-class mines); Tier-2 (Large mines); Tier-3 (Medium size mines) and Tier-4 (Small mines including dykes). Many of the Tier-4 projects are marginal and have seen only sporadic mining activity and only a selection have been listed. A separate section has been allocated to the secondary deposits.

Much of the information on these diamond deposits has been gathered from company reports, press releases, investor presentations, independent resource reports and technical publications. Several summary publications have been very useful in this review such as Janse (2007), Wilson *et al*. (2007), Field *et al*. (2008), as well as the Kimberley Process website.

All references to mineral resources have been standardised for the sake of comparison and estimated densities have been applied to volumes of mined material with respect to the secondary mines. These may not always be strictly accurate but they serve the purpose of this review.

The association of diamondiferous kimberlites with "*rigid cratonic nuclei of respectable antiquity*", was first recognised by Kennedy (1964). Subsequently "Clifford's Rule" was adopted by most diamond explorers (Clifford, 1966). It states that mineralised kimberlites are found exclusively on stable cratons where the minimum age of the last thermal event is 2,500 Ma (i.e. Archaean). These were later termed Archons by Janse (1994). The latest interpretation of the distribution of Archaean blocks (de Wit and Linol, 2015) and the distribution of known kimberlites and related rocks and secondary deposits in Africa, is used throughout this review (Fig. 1). A distinction is made between cratons, being Archaean and stabilised before 2.5 Ga and shields that formed and/or amalgamated in post-Archaean times and within which Archaean blocks are embedded (de Wit and Linol, 2015).

Globally there are close to 7,000 kimberlites and lamproites known in the world (de Wit, 2010) with some 3,000 occurring in Africa. Of these 7,000 known intrusions, approximately 1,000 contain diamonds (De Beers, 2014) and of these, only 67 are, or have been, economically sustainable diamond mines.

Diamond-bearing kimberlites in Africa range in age from Archaean

(Mitzic in Gabon; Henning *et al*., 2003) to Eocene (Mwadui in Tanzania; Stiefenhofer *et al*., 2004), and diamondiferous sediments from Archaean (Witwatersrand Group) to Holocene (inland alluvium in various countries and recent marine deposits along the west coast of southern Africa).

Historical background

The first diamonds reported in Africa were found in Algeria from the Ghoumel River near Constantine (Dufrénoy, 1834). Subsequently, in 1854 diamonds were reported from the Reggane region in south-central Algeria in an area called Bilād al-mās meaning *country of the diamond* (Godard *et al*., 2014) and since 1975 some 1,500 diamonds have been recovered from the Pleistocene alluvial sediments in this area. However, no economic extraction has taken place.

Mining of diamonds started in the south of Africa following rumours of diamonds that had been circulating in the mid-1800s. The first recorded diamond was the 21.25 carat ('Eureka') diamond found along the Orange River on the farm De Kalk, South Africa, by 15-year old Erasmus Jacobs in 1867. This stone attracted some optimistic prospectors who found little and soon gave up. Further finds were made along both the Orange and Vaal Rivers between 1867 and 1869, but it was the 83.5 ct diamond, the Star of South Africa, found in 1869 on the farm Zandfontein close to De Kalk, that really sparked the first rush by prospectors to these new diamond fields. Diamonds were subsequently discovered along the Vaal River at Klipdrift, later renamed Barkly West and in 1870 the first diamond digging operation in South Africa started here at Canteen Koppie (de Wit, 2008). By the end of that year it is estimated that some 5,000 people were living on the diggings (Babe, 1872). However, by early 1871 digging near Klipdrift had reduced dramatically. This drop in activity is attributed partly to other diggings opening along the Vaal (Pniel, Gong Gong, Hebron, Cawood's Hope etc), but more importantly to the discovery of the 'dry' diggings (later to become kimberlite mines) some 30 km east of Klipdrift. These were so named since the weathered upper part of kimberlite pipes, also known as yellow ground, was initially believed to be old river deposits and many diggers moved on once the yellow ground was exhausted not realising that the harder 'blue ground', or fresh kimberlite underneath, also carried diamonds.

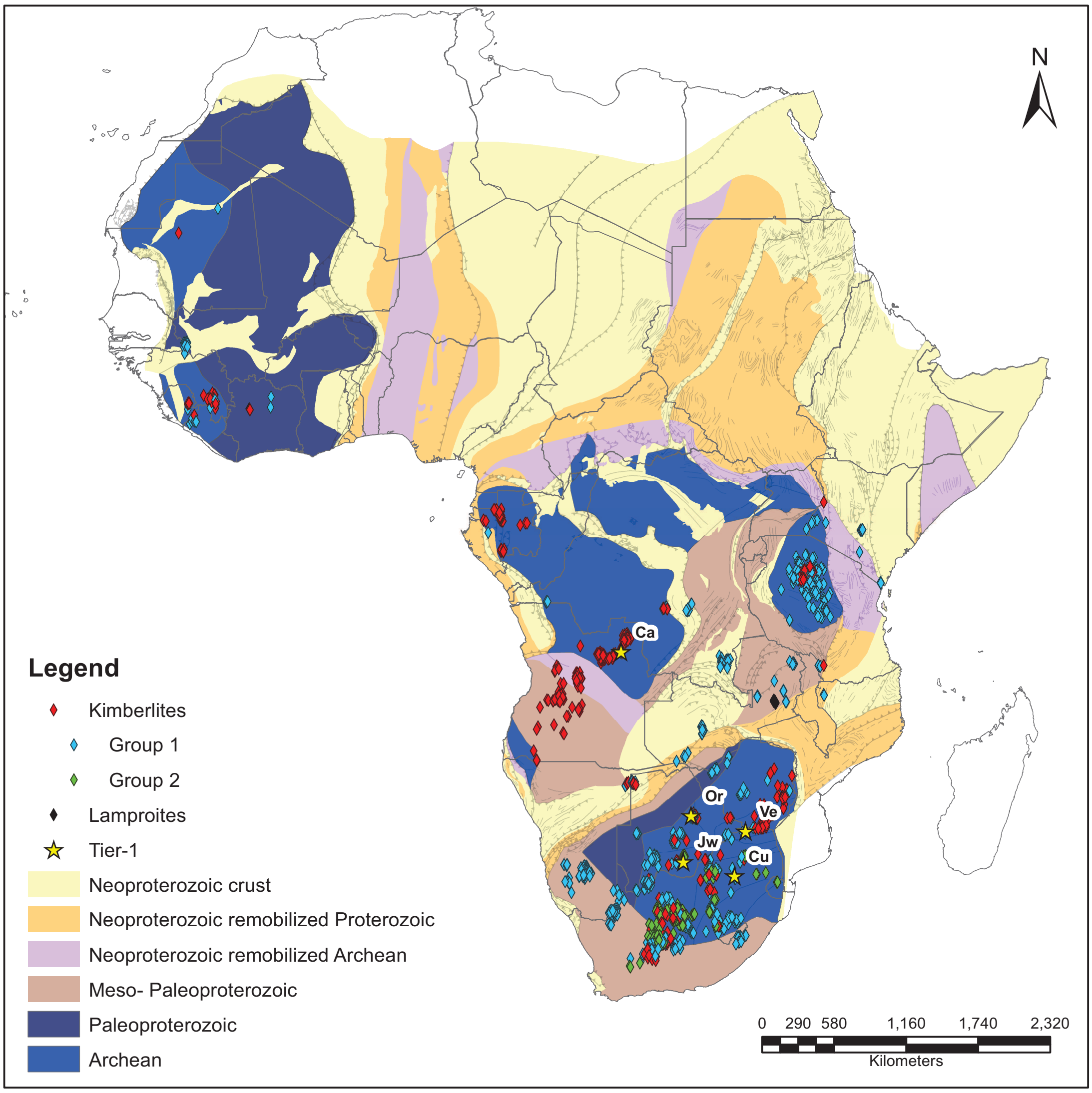

Figure 1. Geological map of the Precambrian basement of Africa (de Wit and Linol, 2015) with all kimberlites (red), those petrographically known as Group 1 (blue) and Group 2 (green) kimberlites, lamproites (black) and Tier-1 diamond deposits, labelled: Ca = Catoca, Cu = Cullinan, Jw = Jwaneng, Or = Orapa, Ve = Venetia.

The Koffiefontein pipe was discovered in July and Jagersfontein in August of 1870. These were followed by the discoveries of the Dutoitspan and Bultfontein pipes in September and December respectively of the same year in what later became the town of Kimberley (Davenport, 2013). It was at Jagersfontein that the first connection between diamond and a hard rock (*viz. kimberlite)* was made. These discoveries were followed by the De Beers, Kimberley (both in 1871), Wesselton (1890), Lace (1896), Cullinan (1902) and Voorspoed (1906) pipes and a host of smaller occurrences discovered between 1870 and 1906, all in South Africa.

The kimberlite discoveries in South Africa were followed by the discoveries of important secondary deposits in Namibia (1908), Democratic Republic of Congo (DRC; Tshikapa - 1906, Mbuji Mayi - 1918), Angola (Lundas - 1912), Central African Republic (CAR - 1913), Togo (1919), Ivory Coast (1929), Sierra Leone and Liberia (1930) and Guinea (1933). The proportion of alluvial diamonds mined over those from kimberlites was much higher during this period. However, this changed with the discovery of the large kimberlite mines such as Williamson in Tanzania (1940), Mbuji Mayi (DRC, 1946), Camafuga Camazamba (Angola, 1952), Finsch (South Africa, 1961), Catoca (Angola, 1968), Orapa (Botswana, 1967), Jwaneng (Botswana, 1973) and Venetia (South Africa, 1980). Although other large secondary deposits were found at Kleinzee (South Africa, 1925), Lichtenburg (South Africa, 1927) and Marange (Zimbabwe, 2001), these could not compete with the sustained production of the kimberlite mines and to date most diamond production has been from primary deposits.

Tier-1 deposits

Only seven of 7,000 known kimberlite occurrences are Tier-1 mines. Tier-1 mines are defined as deposits having more than US$ 20b of contained revenue - from start to depletion (De Beers, 2014) and these account for almost 65% of total global production (Skinner, 2014). Of the seven, five are located in Africa (Fig. 1), Jwaneng, Orapa, Venetia, Catoca and Cullinan (Table 1). Four of these occur on the Kaapvaal Craton in southern Africa and one on the Kasai Craton in central Africa, and they cover an age range from Mesoproterozoic to Cretaceous.

Orapa Mine AK01 (Botswana)

The Orapa AK01 pipe was discovered in 1967 by De Beers and consists of two volcanic conduits that have coalesced near the surface and which had an original area of 118 Ha before mining commenced. Each of the conduits contains distinct kimberlite types (Fig. 2) with different diamond populations. The intrusion is dated at 93.1 Ma (Davis, 1977) and the upper portion of the pipe contains a sequence of epiclastic kimberlite composed of shales, grits, sandstones and debris flows that were formed in a crater-lake. These deposits contained a variety of Cretaceous fossil plants and insects (Rayner *et al*., 1991). The older North Pipe contains crudely layered pyroclastic kimberlite resembling massive volcaniclastic kimberlite (Scott-Smith *et al*., 2013), and not unlike diatreme tuffisitic kimberlite breccia (Clement, 1982), with avalanched basalt breccia lenses around the periphery. The South Pipe has a more complex geology. Three phases of intrusion have been identified, each separated by a sequence of basalt-rich breccias. Massive, steeply dipping basalt breccias are present around the periphery of the western and eastern margins of the pipe.

Mining activities commenced in 1971, and to date 335 Mct have been extracted to a current mining depth of 220 m (Debswana Database, M.A. Roberts, pers. comm., 2015). Recently an average of 14.5 Mt of ore is mined annually generating ~10 Mct/a. Current mining activities are limited to the Cut 2 mining development, with a future Cut 3 being evaluated. Ongoing deep delineation drilling and associated grade sampling has demonstrated in the South Pipe, that the buried southern dark volcaniclastic kimberlite, which has never been previously exploited or sampled, contains grades significantly higher than that of the overlying layered crater facies material. This new discovery of a significant quantity of diamonds at depth provides further value in terms of future expansion options. Current conceptual studies support a potential life of mine at the current rates of extraction, to beyond 2040.

The Orapa Mine lease also includes the potentially economic 3.5 ha (at surface) AK20 diamondiferous kimberlite, the elluvial/ alluvial gravel deposits to the north of the AK1 kimberlite (Airport Pan gravels) and the 160 Mt Orapa Coarse Tailings Mineral Resource (that was built up during the operation of the original plant which did not have a re-crush facility).

Jwaneng Mine DK2 (Botswana)

Jwaneng Mine is located some 160 km west of Gaborone and was discovered in 1972 by De Beers. The pipe is covered by some 50 m of Kalahari Group sediments and forms part of the

Table 1. Tier-1 deposits: World class mines

Tier-1 Diamond mines in Africa: Resources – Indicated and inferred (incl. reserves)										
Mine	Discovered	Age (Ma)	Group	Ha	Tonnes (Mt)	Grade (cpht)	Contained diamonds (Mct)	Cut-off (mm)	LOM (yrs)	Mct/a
Orapa*	1967 De Beers	93	1	118	505.2	70.9	363.7	1.65	21 (Cut 3)	11.16
Jwaneng*	1972 De Beers	240	1	54	320.4	119.5	343.1	1.47	20 (Cut 8)	10.64
Cullinan°	1902 Cullinan	1,115	1	32	428.7	46.6	199.6	1.00	+50	0.89
Venetia* (K01 – K03)	1980 De Beers	519	1	23.3 (3x)	238.1	103.4 (OP) 87.8 (UG)	192.9	1.00	27 (UG)	3.07
Catoca§”	1968 Diamang	118	1	63.6	217	64.5	140		30	6.7
Total					**1,709.4**	**72.5**	**1,239.3**			**32.5**

°Petra Diamonds Resources and Reserves at Cullinan June 2013. *Anglo American Ore Reserves and Mineral Resources report 2013. §” Angop press Release Jan 2012. OP = open pit, UG = underground.

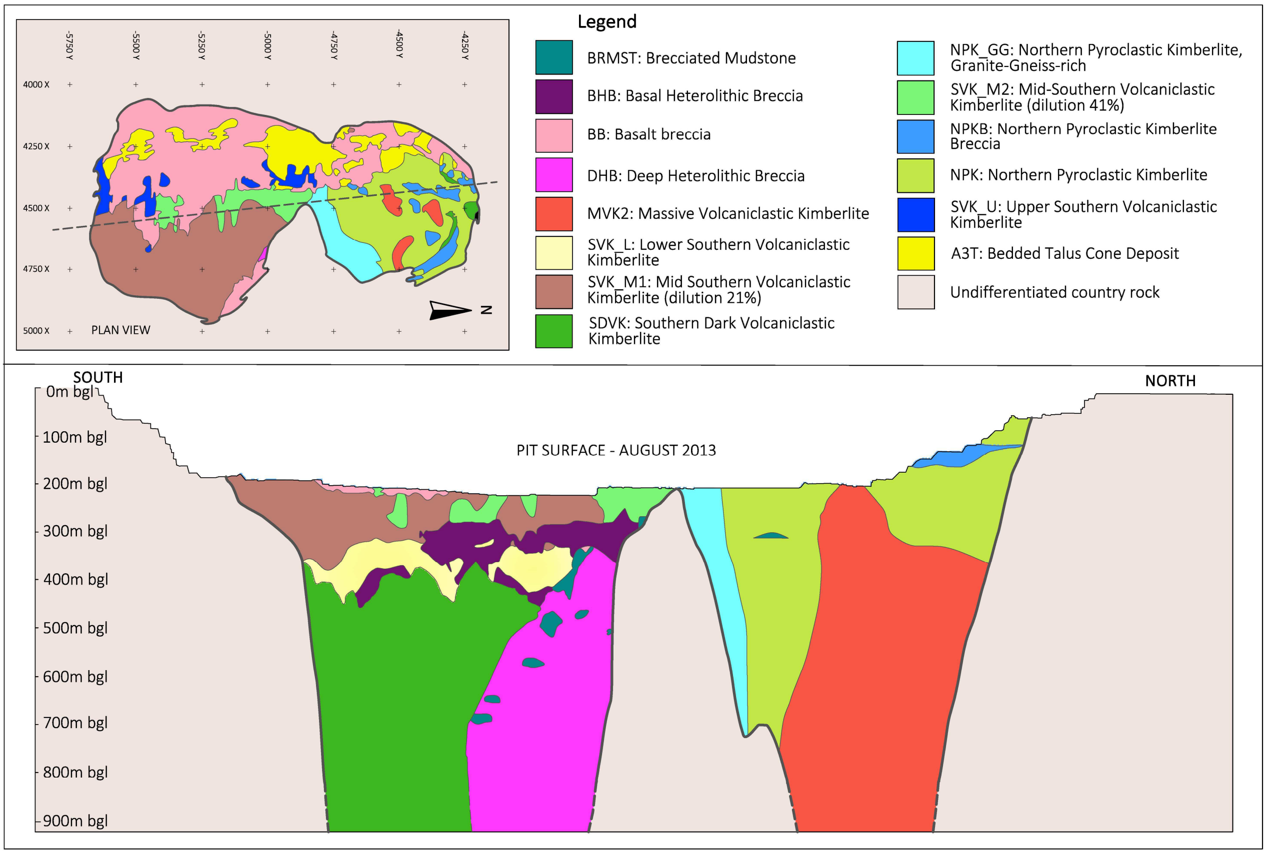

Figure 2. Schematic geological section (N-S) of the Orapa open pit with the outlines of the current pit (Courtesy Debswana).

Jwaneng kimberlite cluster which includes 11 other kimberlites.

The Jwaneng pipe was emplaced at approximately 240 Ma (Burgess *et al*., 1992) and intrudes Late Archaean to Palaeoproterozoic Transvaal Supergroup carbonates and shales. It comprises at least six kimberlites of which four have been modelled (Fig. 3). The three primary intrusions are known as the Centre, South and North Pipes which coalesce and have an original surface area of 54 ha. The order of emplacement is believed to have been South, Centre and then North. The South and Centre pipes contain a core of massive volcaniclastic kimberlite overlain by re-sedimented volcaniclastic kimberlite. The rims of these two lobes are dominated by units that include localized country rock breccias and sheared kimberlite, showing downward propagation along the kimberlite contact. These rim units also include rafts and fragments of Lower Karoo Supergroup mudstone, demonstrating that Lower Karoo sediments were present during emplacement of the kimberlites, but have since been eroded. At depth, Centre Pipe contains a broad wedge of country rock breccia that formed during deep level explosions in the latter stages of the kimberlite emplacement. North Pipe is different compared to South and Centre Pipes, as the central core is comprised of mainly pyroclastic units that are thickly bedded and include interbeds of finer volcaniclastic and in places ashy kimberlite. A fourth pipe occurs (Fig. 3), which contains of highly diluted volcaniclastic kimberlite and represents a vent that did not develop completely. Figure 3 is a plan and cross section of the DK2 kimberlite at Jwaneng and shows the distribution of the various rock types.

Mining commenced in 1982 and to date the mine has produced 341 Mct (Debswana Database, M.A. Roberts, pers. comm., 2015). Together with the high quality of the Jwaneng diamonds, this volume of carat production has made Jwaneng the most valuable mine of any commodity in the world. Current production generates approximately 12 Mct/a from about 8 Mt of ore and the present resource suggests some 343.1 Mct of contained diamonds remain in the ground (Table 1). Conceptual studies indicate a potential economic life of mine beyond 2040 at current levels of production.

In addition, the tailings resource at Jwaneng created during early periods of production before the implementation of a re-crush circuit, is now being exploited through a dedicated tailings re-treatment facility which will produce an additional ~0.9 Mct/a until 2030. The diamondiferous DK7 kimberlite also lies within Debswana's Jwaneng Mining Lease Area.

Cullinan Mine (South Africa)

Cullinan, located some 37 km east-northeast of Pretoria, is one of the world's most celebrated diamond mines and is a source of large, high-quality Type II gem diamonds and a regular supplier of rare blue diamonds. It earned its place in history with the discovery of the 3,106 ct Cullinan Diamond in 1905, the largest rough gem diamond ever found, which was presented to King Edward VII by the Transvaal government as a birthday gift and today forms part of the Crown Jewels of England. The mine has produced over 700 stones of more than 100 ct and more than a quarter of all the world's diamonds of larger than 400 ct.

The Cullinan pipe, which was discovered in 1902 by Thomas Cullinan and initially known as the Premier Mine, is the only economically viable kimberlite in a cluster of 11. The original surface area was 32 ha and is kidney shaped with dimensions of 860 x 400 m

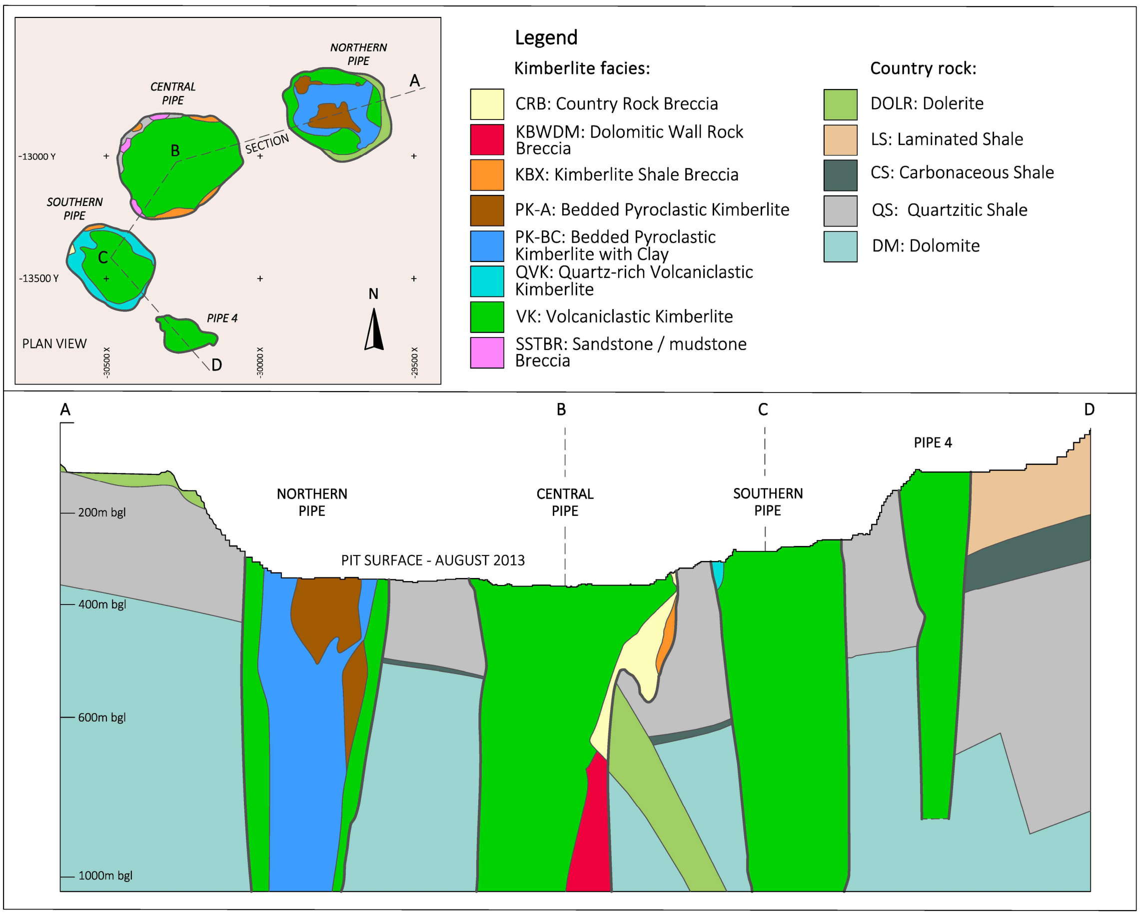

Figure 3. Cross-section showing internal geology of the Jwaneng DK2 kimberlite (Courtesy Debswana).

elongated along a northwest-southeast direction. It intrudes fenitized quartzites of the Paleoproterozoic Waterberg Group at surface and Transvaal Supergroup sediments and the main zone of the Bushveld Complex at depth. Large rafts of Waterberg quartzite and conglomerate exist in the pipe. It is estimated that the top 300 m of the original pipe has been eroded since the pipe was intruded at 1151 Ma (Wu *et al.*, 2013).

There are three major kimberlite phases within the pipe. Two of these are typical volcaniclastic kimberlite (known as the Grey/Brown tuffisitic kimberlitic breccia and Black/Green transitional tuffisitic kimberlitic breccia), whilst the final phase of intrusion is a coherent kimberlite core complex in which four kimberlite types and late-stage dykes have been identified (Fig. 4). The kimberlite was cut by a 75 m thick gabbro sill dated at 1115 Ma (Allsopp *et al.*, 1967) at a depth of between 380 and 500 m below surface which metamorphosed the kimberlite to a distance of 15 m from the contacts.

Mining commenced in 1903 from an open pit. Grades showed a steady decline from 106 cpht in 1904 to 27 cpht in 1913. Production ceased in 1915 but resumed at much lower tonnages in 1916. De Beers gained control of the mine in 1926 and production averaged 4.5 Mt/a, at an average grade of 30 cpht until 1932 when the mine was closed after the open pit had reached a maximum depth of 189 m. After the second world war two vertical shafts were sunk to access the ore body and in 1950 diamond production recommenced from underground workings. Production was built up to an average of 5.3 Mt/a between 1964 and 1988. Petra Diamonds acquired the mine in 2008. In total the mine has produced approximately 145 Mct from roughly 435 Mt of ore at an average grade of 35 cpht. In 2013 Cullinan produced 0.87 Mct with 0.80 Mct from mined material and 0.07 Mct from tailings. Petra Diamonds is hoping to increase the production of the mine to 2.2 Mct in 2019. Its resources are listed in Table 1, and in 2014 production was valued at 144 US$/ct but if the special stones are included, the value increases to 185 US$/ct (Petra Diamonds, 2014a).

Venetia Diamond Mine (South Africa)

In 1980, De Beers discovered 13 kimberlite pipes and a dyke (Fig. 5), on the farm Venetia some 540 km north of Johannesburg. The current Mineral Resource comprises the K01, K02 and K03 pipes, which total 23.3 ha at the current land surface. K04 is the only other kimberlite of significance at just over 4 ha in size, but with appreciably lower diamond grades. The regional structure exerted a significant control on emplacement, resulting in a prominent west-northwest orientation in pipe shapes (Kurszlaukis and Barnett, 2003). The kimberlites have been dated at 519 Ma (Phillips *et al.*, 1999) and they intrude the 2.0 Ga Central Zone of the Limpopo Mobile Belt which comprises gneiss, amphibolite, schist, quartzite and marble. However, Archaean lithosphere is believed to exist beneath this collision zone (Stankiewics and de Wit, 2013).

The current pipe model extends to a depth of 1,044 m below surface. The K01 kimberlite is the principal orebody and comprises mainly volcaniclastic kimberlite crater in-fill in the upper levels of

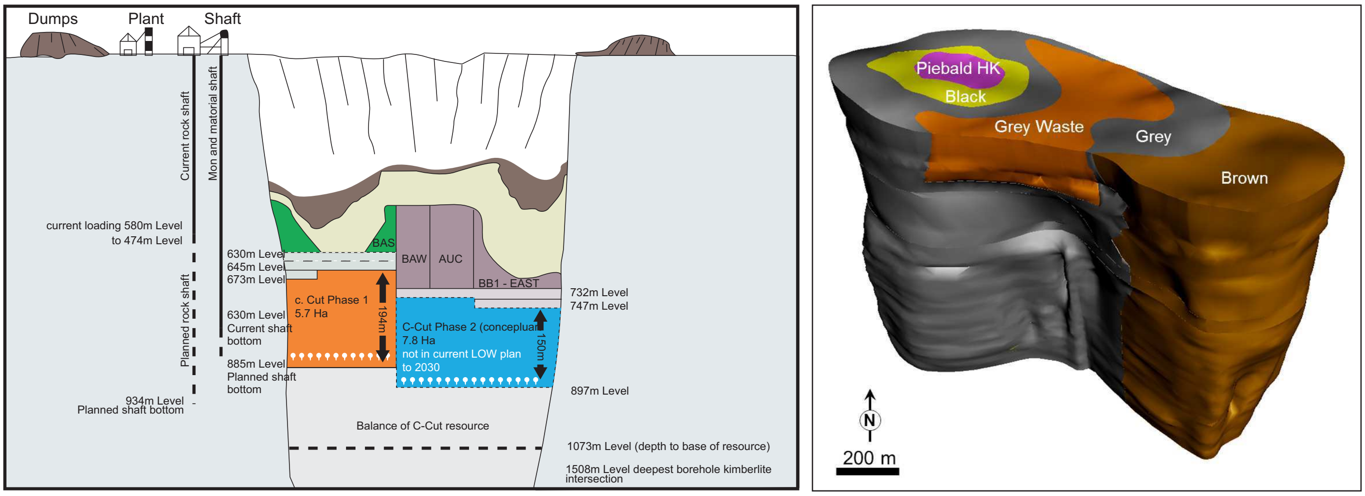

Figure 4. Schematic section of Cullinan Diamond Mine (left) and model of the main kimberlite geological domains (right) (Courtesy Petra Diamonds).

the pipe (unit MVK, Fig. 5). K01 also contains areas of coherent kimberlite which have been interpreted as eruptive point sources within the main pipe, some with their own unique diamond signature. The presence of country rock breccias and re-sedimented volcaniclastic kimberlite, particularly along the western rim of the pipe, suggests the presence of side-wall and tuff-ring collapse into the pipe.

Production commenced in 1992. K01 is characterised by the highest diamond grade and revenue, followed by K02, K03 and lastly K04. The coherent kimberlites from K01 may contain a different diamond population from that of the average total production. For example unit CK-NE (Fig. 5) contains a notable proportion of brown diamonds in comparison to the other domains in K01. Large diamonds (+10.8 ct) are recovered on a weekly basis at Venetia. These are typically light yellow and resorbed octahedral morphologies, as well as rejection stones with multiple imperfections. The average Venetia diamond production is comprised of near colourless to grey dodecahedral goods with some brown and rare yellow diamonds. Type II diamonds are rare. The K03 pipe exhibits a higher proportion of cubic stones with green radiation spots on the surfaces. To date Venetia has produced approximately 108 Mct from 93 Mt (De Beers annual reports) at an average grade of 116 cpht.

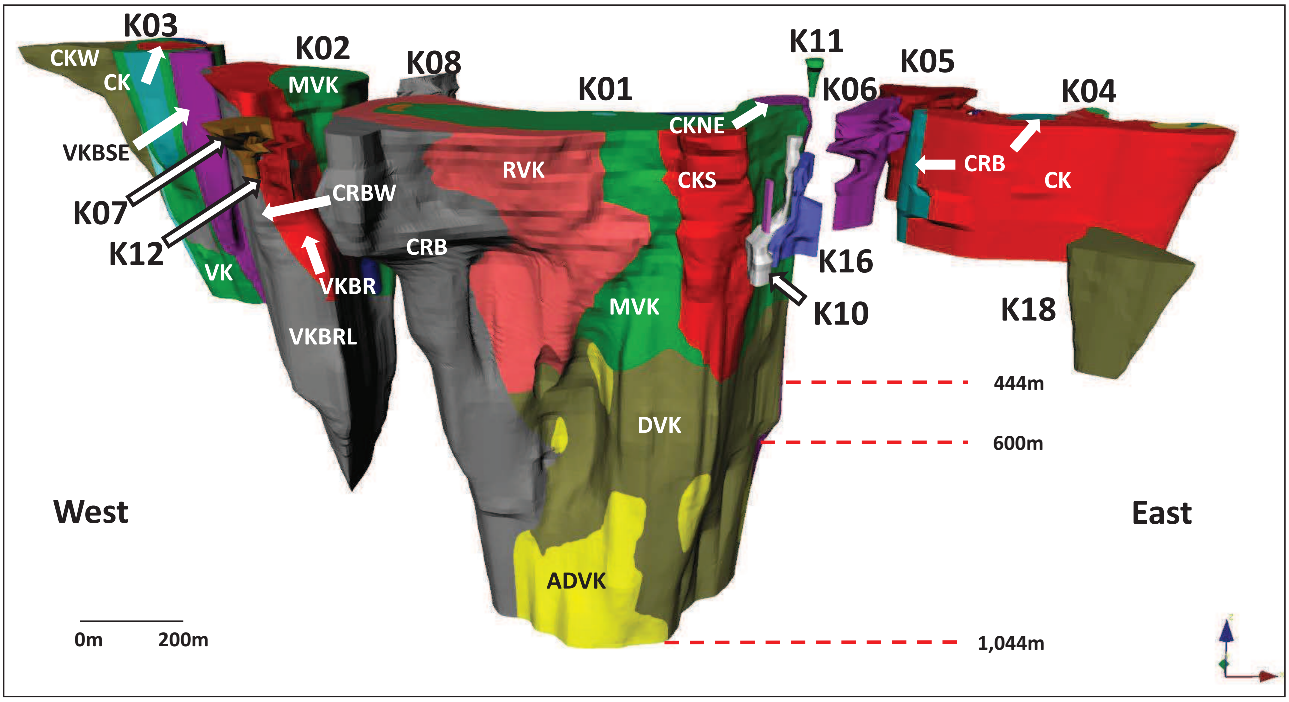

Figure 5. Geological model of the most significant kimberlites within the Venetia kimberlite cluster shown looking north. The strong structural control on the emplacement of these pipes is readily apparent (Courtesy De Beers Consolidated Mines (DBCM)). CRB = country rock breccia, RVK = reworked volcaniclastic kimberlite, MVK = massive volcaniclastic kimberlite, VK = volcaniclastic kimberlite, CK = coherent kimberlite, HK = hypabyssal kimberlite.

Catoca Diamond Mine (Angola)

The Catoca kimberlite was discovered in 1968 by DIAMANG (Companhia de Diamantes de Angola), some 30 km north-northwest of Saurimo in northeast Angola. It is the largest of about 70 kimberlites reported in the Catoca cluster within an area of 350 km^2, in the vicinity of the Lova and Chicapa river basins (Pervov *et al*., 2011).

Catoca is a partially eroded crater with original dimensions of 990 x 915 m (63.6 ha) at surface. The country rocks comprise Archaean granite-gneisses and schists. The pipe is overlain by sands of the Kalahari Group, which range up to 60 m in thickness. In vertical cross section the pipe has a pronounced champagne-glass shape, narrowing to about 300 x 400 m at less than 300 m from surface (Fig. 6). The upper part of the pipe is characterised by crater infill with a central basin of low grade sediments. At about 200 m the pipe has a transition zone marked by a pronounced breccia layer, below which are pyroclastic rocks of the diatreme zone. The pipe is dated at approximately 118 Ma (Robles-Cruz *et al*., 2012).

Production began in 1997 and in its first full year of operation the mine produced 1.2 Mct. It had doubled its capacity by mid-2005 and up to 2012 has produced 67 Mct from 97 Mt of ore at an average grade of 60 cpht. Current production is approximately 6.7 Mct/a with an average diamond value of 86 US$/ct. The mine is operated by Sociedade Miniera de Catoca Ltda. (SMC), a joint venture between Endiama 32.8%, Alrosa 32.8%, LL International Holding BV 18% and Odebrecht 16.4%. It is the fifth largest producer by value and the sixth largest by carats in the world (Table Toppers, Paul Zimnisky, Mining Journal). The resource estimates (Table 1) are from Porter Website (2002) and for 2012 from Ganga Junior (Angop Press, January 2012).

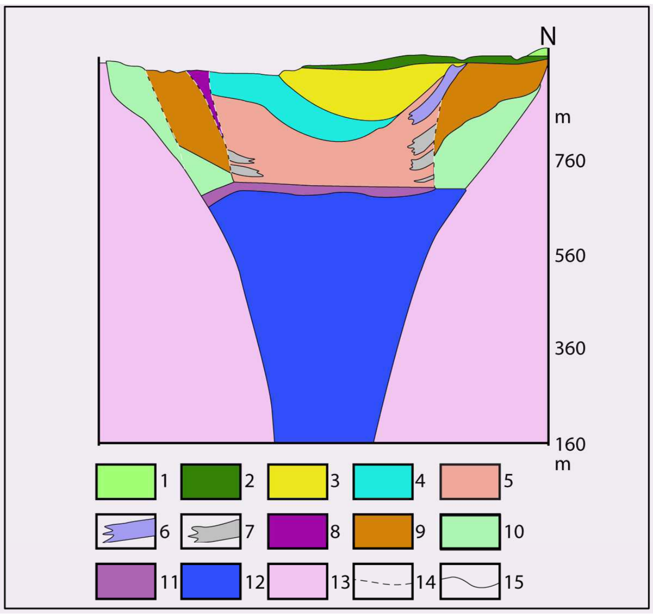

Figure 6. Schematic geological section across the Catoca pipe. 1. Kalahari Group; 2. IFS -2 (poorly cemented sandstone); 3. IFS-1; 4. Upper VSR (tuffaceous sand-, silt-, mudstone) (TKB-2); 5. Lower VSR; 6. VSR; 7. VSR reworked; 8. TZ (kimberlitic tuff); 9. KBM (banded tuffisitic kimberlite); 10. TKB-1 (tuffisitic kimberlite breccia); 11. XL (kimberlitic tuff and bedrock breccia); 12. AKB (tuffisitic and coherent kimberlite); 13. Archean basement; 14. Faults (after Pervov et al., 2011).

Tier-2 diamond mines

Tier-2 , -3, -4 deposits are smaller and lower value deposits and generally make up some 80% of the deposits that contribute 20% to global production (Rio Tinto, 2011). For the purpose of this summary Tier-2 is defined as mines that have produced more than 0.4 Mct/a for at least five consecutive years, but which do not meet the revenue criteria of Tier-1. Ten such deposits have been identified in Africa (Table 2) and all occur on the Kaapvaal/Zimbabwe and Kasai Cratons and range in age from Cambrian to Cretaceous (Fig. 7).

Table 2 lists the estimated resources for each project. The tonnes column is the sum of the indicated and inferred resources and is generally inclusive of any reserves.

Mbuji Mayi Kimberlite Cluster (Democratic Republic of Congo)

Forminière (Société international Forestière et Minière du Congo) discovered diamonds close to Mbuji Mayi in 1918, but it was not until 1946 that it was recognized from an electrical survey that the rich eluvial deposits were underlain by kimberlite (Magnée, 1974). The discovery of this first kimberlite 'Massif 1' triggered more exploration and resulted in the discovery of a cluster of ten 'Massifs' (M1-M10), six of which are crater- to diatreme-facies pipes and four are topographic in-fills of kimberlitic sediment. Sizes of the surface areas are variable; M1 (22.6 ha), M5 (10.2 ha), M6 (4.4 ha) and M4 (0.8 Ha) (Fig. 8).

The kimberlites are aligned along an east-west trend (Fig. 8) and were emplaced at ca. 70 Ma (Davis, 1977; Shärer *et al*., 1997) through Archaean basement, Proterozoic sandstones and carbonates and Cretaceous arenaceous sediments. Narrow feeder pipes have intruded through the hard limestones and expanded dramatically into the overlying unconsolidated sediments and resulted in 'champagne glass-shaped' intrusions (Fig. 8). The upper parts of the kimberlites show crater facies litho-types, including re-sedimented volcaniclastic kimberlite and pyroclastic kimberlites. The volcaniclastics comprise green and red breccias and tuffs, with variable dilution and often show graded bedding (Wasilewski, 1950). The pyroclastics are characterized by juvenile-rich micaceous kimberlite units on the scale of metres to decametres that have a massive appearance. Coherent kimberlite is largely absent.

Kimberlite grades are variable from 25 cpht in the "epiclastic" kimberlite, to 70 cpht in volclanicalstic kimberlite, to 90 to 130 cpht in massive pyroclastic kimberlite. The stone value is generally low, averaging between 12 and 14 US$/ct.

The MIBA (Société Minière de Bakwanga) mining operations are marginal since most massifs have been mined out. At this stage the main resource that is left is the hard M1 (Table 3) and small portions of M4, M5 and M6 that can still be mined and in 2007 just over 60 Mt was left as a resource (Kabonga, pers. comm., 2008).

Secondary deposits include sandy argillaceous deposits that overlie the kimberlite pipes and hill slope gravels and run at grades of up to 400 cpht. Alluvial deposits inclusive of high and low terrace and valley floor deposits occur along the Mbujimayi, Sankuru and Lubi rivers (and associated tributaries), along with riverbed gravel deposits, particularly in the Mbujimayi and Sankuru rivers. Potholes within the rivers have proven to be excellent diamond trap-sites with reported grades of up to 4,500 ct/t.

Table 2. Tier-2 deposits: Large mines

Tier-2 Diamond mines in Africa (+0.4 Mct/a): Resources – Indicated and Inferred (incl. reserves)										
Mine	Discovered/ Discoverer	Age (Ma)	Group	Ha	Tonnes (Mt)	Grade (cpht)	Contained diamonds (Mct)	Cut-off (mm)	LOM (yrs)	Mct/a
Tshibwe (DRC)	1955 Miba		1	60	107.4	56.8	61.0		18	3 - 6 (2016)
Mbuji-Mayi (DRC)	1946 Forminiere	71	1	22.6 (M1)	61.2	88.8	54.3		>50	0.8 -1
Finsch° (RSA)	1960 Fincham/ Schwabel	118	2	17.9	85.2	60.2	51.3	1.00	16 (UG)	1.4
Liqhobongu (Lesotho)	1957 Diggers	85 and 90	1	8.6	89	29	25.8	1.00	15	1.1
Ghaghoo[+] (Botswana)	1981 Falconbridge	87	1	10.3	108.2	18.98	20.5 (524 m)	1.50	15	0.5
Murowat (Zimbabwe)	1997 Rio Tinto	538	1	4.5 (2x)	19	90	17.1		20	0.4
Lace/Crown[2] (RSA)	1896	133.2 ± 2.8	2	2.9 (2x)	35.6	40.12	13.4	1.00	25	0.4 – 0.5
Karowe[3] (Botswana)	1970 De Beers	88 and 93	1	9.5	69.1	15.4	10.7 (750 m)	1.25	15	0.4
Voorspoed* (RSA)	1906 Harger	131	2	12	33.0	21.8	7.2	1.47	10	0.61
Lethlakane* (Botswana)	1970 De Beers	93?	1	15.2 (2x)	18.5	28.4 OP 24.8 Tail	4.9	1.65	4 (OP)	1.03
Total					**626.2**	**44.8**	**266.2**			**9.63**

°Petra Diamonds Resources and Reserves at Cullinan June 2013. *Anglo American Ore Reserves and Mineral Resources report 2013. [+]Venmyn Deloitte Jun2014. [2]DiamondCorp June 2014 (production starts in 2015). [3]Lucara NI 43-101 Independent Technical report February 2014. [3]Rio Tinto Diamond 2013. [4]Liqhobong DFS October 2012.

Tshibwe (Democratic Republic of Congo)

In 1955 kimberlite was intersected in extensive eluvial workings in the Tshibua area 30 km southwest of Mbuji Mayi. This Tshibwe kimberlite pipe which forms part of a cluster of six kimberlites (Fig. 8) is located in an east-west orientated valley surrounded by low hills. Dredging of the Mbujimayi gravels below the confluence of the Tshibwe drainage and the Mbujimayi River, has proven lucrative with the 100 m wide by 20 m deep Senga-Senga pothole (Fig. 8) delivering 5 Mct from 0.25 Mt of ore.

Estimates of the extent of the kimberlite sub-outcrop range from 40 to 60 ha. The pipe has an east-west orientation with dimensions of approximately 1400 x 600 m. In cross-section, the pipe has a flared champagne-glass shape, with a narrow neck some 200 m in diameter (Fig. 9). The pipe is dominated by volclanicalstic kimberlite, including sandstone-rich, monolithic and heterolithic breccia types (re-sedimented volcaniclastic kimberlite), as well as the more competent, green-grey, massive pyroclastic kimberlite and transitional kimberlite types (de Wit and Jelsma, 2015).

The eluviated and weathered surface horizon (“yellow ground”) over the Tshibwe pipe was mined by MIBA between 1978 and 1980, with reported grades in excess of 90 to 100 cpht. The diamond potential of the hard “blue ground” kimberlite of the pipe was subsequently mined between 500 m and 670 m by MIBA (1981-2000), Sengamines (2001-2005) and SACIM (Société Anhui-Congo d’Investissement Minier Sprl) (2013-present). The Sengamines operations produced 2.03 Mct at a run-of-mine grade of 38.1 cpht and revenue of 16 US$/ct (Michaelides, 2006).

Finsch (South Africa)

The Finsch kimberlite, situated approximately 165 km northwest of Kimberley, was discovered in 1960 by two prospectors, *Fin*cham and *Sch*wabel while prospecting for asbestos. The main pipe is located on the northeast striking Smuts dyke and forms part of the Finsch kimberlite cluster which is made up of three pipes (Finsch, Shone and Bowden) and three sets of dykes (Botha, Smuts and Bonza).

The mine was opened in 1967 and has produced approximately 130 Mct of diamonds. The open pit was mined to a depth of 423 m and full production from underground began in 1990. De Beers operated the mine until 2011 when it was purchased by Petra Diamonds. Present operations are between levels 510 and 630 m (Block 4). Treatment of pre-1979 tailings (before the plant upgrades in 1980), commenced in 2003 and contribute significantly to current production.

Finsch is a Group II kimberlite pipe dated at 118 ± 2.8 Ma. (Smith *et al*., 1985) and had a surface area of 17.9 ha before mining commenced. The country rock is composed of lithologies of the Griqualand West Sequence of the Transvaal Supergroup (andesites and banded iron formation). The presence of Karoo basalt, sandstone, mudstone and shale breccias, in the pipe suggest that a large part of the Karoo Supergroup sequence was in place at the time of emplacement (de Wit *et al*., 2009).

The pipe infill is mainly pyroclastic kimberlite breccia with a

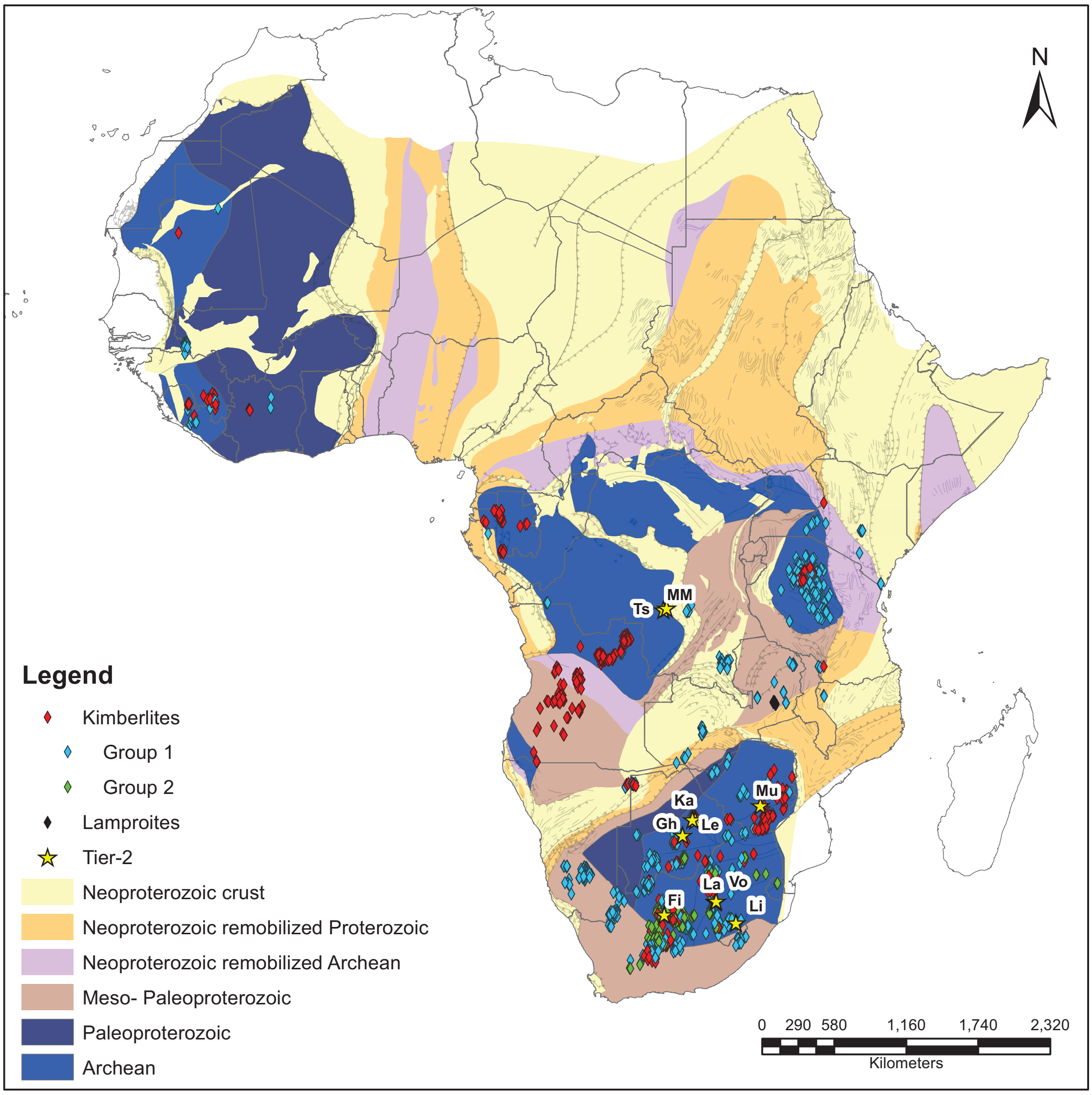

Figure 7. Geological map of the Precambrian basement of Africa (de Wit and Linol, 2015) with known Group 1 (red) and Group 2 (blue) kimberlites, and lamproites (purple), highlighting Tier-2 diamond deposits, laballed: Fi = Finsch, Gh = Ghaghoo, Ka = Karowe, La = Lace, Le = Letlhakane, Li = Liqhobong, MM = Mbuji Mayi, Mu = Murowa, Ts = Tshibwe, Vo = Voorspoed.

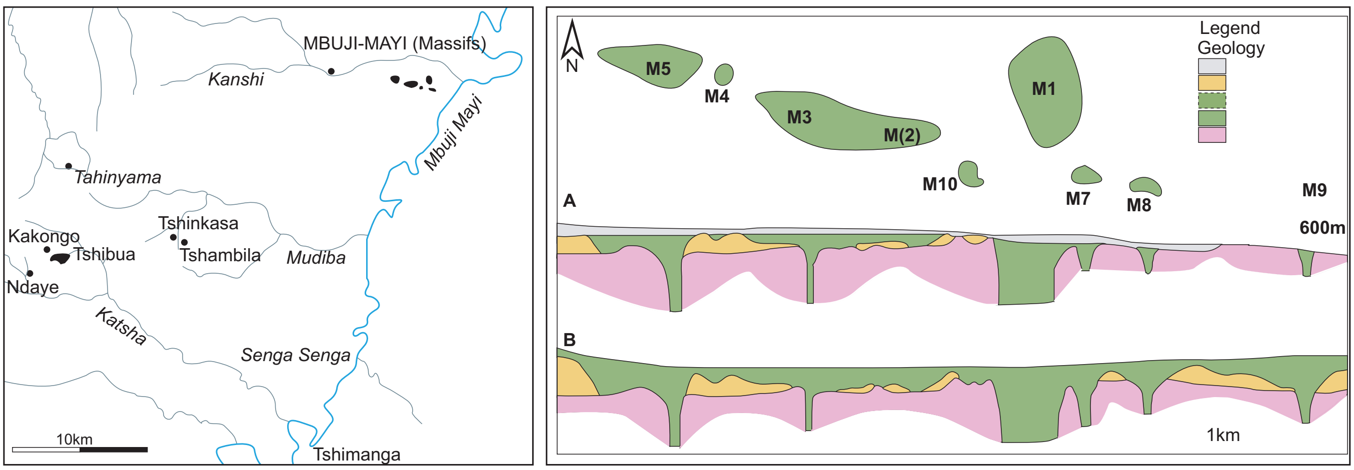

Figure 8. Map of the kimberlite pipes near Mbuji Mayi and Tshibwe in the Eastern Kasai Province of the Democratic Republic of Congo (left side); and the plan view of the Mbuji Mayi pipes, longitudinal profile (A), and theoretical reconstruction of the profile before erosion (B) (after Fieremans and Fieremans, 1993) (right side).

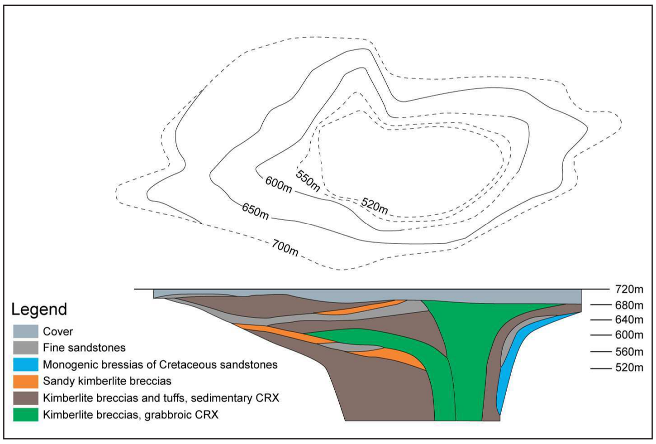

Figure 9. Tshibwe pipe, topographic contour map of crater/wall rock contacts as deduced from drilling, and longitudinal profile (redrawn from Fieremans and Fieremans, 1993).

number of magmatic precursors, plugs and dykes. A total of four major precursor bodies surround the main pipe and a total of eight kimberlite phases (F1 to F8), are recognised within the pipe (Ekkerd *et al*., 2003).

The development of Block 5 (from 630 to 900 m depth) is underway and will be using the Sub Level Caving (SLC) mining method to a depth of 780 m, after which a conventional block cave is planned to 900 m. The current resources for Finsch are shown in Table 2 (Petra Diamonds, 2014b).

Finsch produces several +50 ct stones annually. In addition, the mine is known for highly commercial goods of +5 ct and is rich in gem quality smaller diamonds. Average diamond value at Finsch is 99 US$/ct (2014).

Liqhobong (Lesotho)

Liqhobong is a large circular pipe with an original extent of 8.6 ha at an elevation of approximately 2,650 m, and it has a satellite pipe originally 1 ha in size just to the west (Nixon and Boyd, 1973). It is located some 27 km west of Letseng (Fig. 10). The main pipe contains four major distinct kimberlite varieties, each characterised by different diamond types.

Trial mining between 2011 and 2013 produced 1.1 Mt of kimberlite and recovered 0.32 Mct at an average grade of 29 cpht and a price of 93 US$/ct. This has been revised to 107 US$/ct for an inferred and probable resource of 29 Mct to 320 m below surface (RBC Capital Markets, January 2015). Firestone Diamonds plc is currently developing a new mine with planned full production of over 1 Mct/a which is reported to start production in 2016.

Ghaghoo (Botswana)

The Ghaghoo pipe, previously known as Gope Go25, was discovered in 1981 by Falconbridge in a cluster of nine kimberlites (Lee *et al*., 2009). However only Ghaghoo has proven to be economic and was recently acquired by GEM Diamonds who opened the mine as an underground operation in 2014. The 10.3 ha pipe is covered by approximately 80 m of Kalahari sediments and is situated inside the southeastern portion of the Central Kalahari Game Reserve in central Botswana (Fig. 7).

There are five distinct kimberlite domains within the pipe: two volcaniclastic kimberlite units which appear similar but are distinguished on grade; two basalt breccia units which have a dilution of 44 and 48 percentage basalt respectively and coherent kimberlite which contains less than 10% basalt dilution and increases in volume with depth. The pipe has intruded sediments of the upper Karoo Supergroup and is of Cretaceous age probably around 87 Ma, based on other Cretaceous kimberlites in Botswana. Its mineral resource is presented in Table 2.

Murowa (Zimbabwe)

In 1997, Rio Tinto discovered three diamond-bearing kimberlite pipes and multiple kimberlite dykes that were emplaced into the Archaean basement in the Murowa area in south-central Zimbabwe (Fig. 11). The Murowa Mine was commissioned in 2004 and comprises K1 (2.5 ha) and K2 (2 ha) (Moss *et al*., 2012). K1 is irregular in shape and the pipe infill is internally complex with at least 5 main kimberlite types comprising three coherent kimberlite and two volcaniclastic kimberlite units. Multiple kimberlite dykes cross-cut both the pipe and the country rock. K2 is a steep sided, sub-circular and slightly elongate pipe but its infill is simpler with only one main coherent kimberlite type. A second volumetrically minor kimberlite type, also coherent kimberlite, is preserved locally near the pipe margins. This pipe is also cut by late stage kimberlite dykes (Moss *et al*., 2012). The age of emplacement is inferred at 538 Ma based on association with the nearby Sese kimberlites (Bulanova *et al*., 2012).

In 2011 the Murowa diamond resources were estimated at 7.1 Mct. More recently the

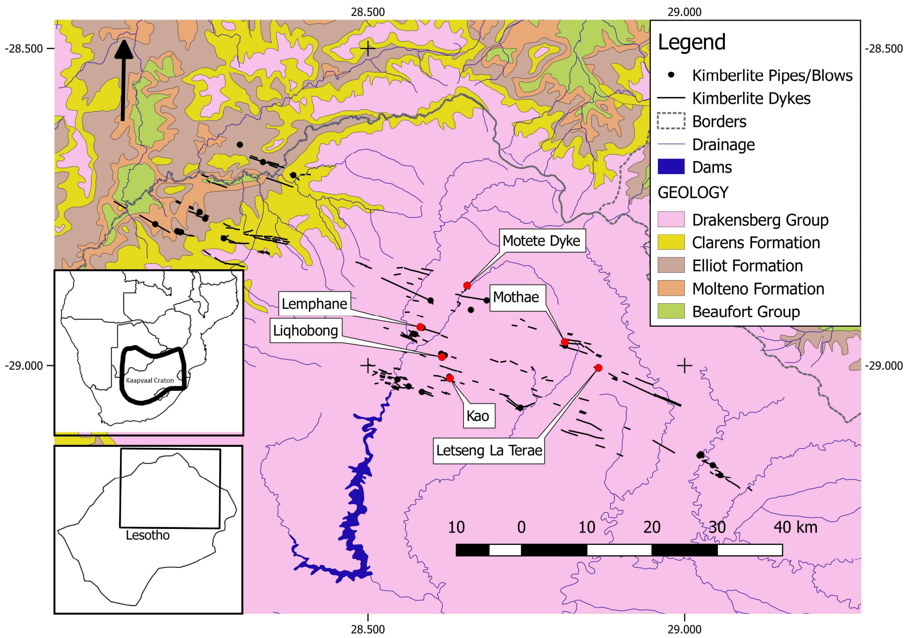

Figure 10. Position of the kimberlites in Lesotho in relation to the regional geology (Courtesy Mike Scott and Associates (MSA).

Figure 11. Google Earth image (2014) of the Murowa Mine in south-central Zimbabwe.

mineral resource, covering all three kimberlites, is estimated at 16.5 Mt grading at 90 cpht with an average price of 65 US$/ct (Rio Tinto).

In 2012 the mine produced some 0.40 Mct from 0.54 Mt and has the capacity to produce this annually (*www.murowadiamonds.com*). Up to the end of 2013 the mine had produced 2.5 Mct (Metals Economics Group, 2013).

Lace Mine (South Africa)

Lace Mine, discovered in 1896, is located some 200 km southwest of Johannesburg and less than 10 km southwest of Voorspoed (Fig. 7). Production started in 1902 and it was mined on and off until 1931. De Beers re-acquired the mine in 1939 but sold it to Diamondcorp in 2005 (Sobie, 2006) and the mine is scheduled to re-commence production as an underground operation in the second half of 2015.

Lace is a Group 2 kimberlite with an age of 133.2 ± 2.8 Ma (Field *et al*., 2008). It was 2.6 ha in extent at surface but increases in size with depth. The diatreme-facies kimberlite comprises tuffisitic kimberlitic breccia (volcaniclastic kimberlite) characterised by abundant quartz and feldspar grains scattered throughout the rock (Clement, 1982). There is a small satellite pipe (0.3 ha) to the west of the main pipe (Howarth, 2010).

Recent bulk sampling suggests that 80% of the diamonds are gem quality and 40% are larger than 1/3 ct in size. A mineral resource of 35.6 Mt with a grade of 40.1 cpht (13.4 Mct) has been declared (DiamondCorp PLC Presentation, June 2014) and the mine is scheduled to produce just over 0.4 Mct/a over the life of mine which is projected to be 25 years (Table 2).

Karowe (Botswana)

The Karowe Mine exploits the AK6 kimberlite pipe which was found in 1970 by De Beers and is part of the Orapa kimberlite field. Initially it was defined as a 3.5 ha kimberlite but was later increased to almost 9.5 ha because the upper section of part of the pipe is characterised by a previously unrecognised basalt breccia. The kimberlite consists of three lobes, North, Central and South, which coalesce near surface. Below 120 m the lobes separate into three distinct pipes that decrease in volume with depth. The South lobe makes up some 72% of the resource in volume (Lynn *et al*., 2014b) which is presented in Table 2.

The kimberlite differs between lobes, with distinctions apparent in the textural characteristics, relative proportion of internal country-rock dilution and extent of weathering. The South Lobe differs most from the North and Central Lobes. The North and Central Lobes exhibit significant textural complexity whereas the bulk of the South Lobe is more massive and internally homogeneous. U/Pb dating has given ages of 88±5 Ma for the Central Lobe and 93±2 Ma for the South Lobe suggesting that the North and Central Lobes are separate and later intrusions. The South Lobe is dominated by pyroclastic kimberlite, whereas the North and Central Lobes comprise various breccias and fragmental volcaniclastic kimberlite types (Lynn *et al*., 2014b).

Lucara Diamond Corporation acquired the AK06 kimberlite in 2010. It opened the Karowe Mine in 2012 with a 15 year life of mine and in 2014, produced 0.43 Mct (Table 2). The mine is a major producer of large, high-value diamonds including the 203.9 ct and 342 ct stones (Fig. 12), as well as the 1,111 ct, 813 ct and 374 ct stones recovered in 2015. These are some of the largest diamonds ever to have been recovered from the Orapa kimberlite field in over 40 years of production. In 2014, special diamond tenders (sales of Karowe's largest gems) totaled 50 stones sold for 136 US$m, including 40 stones valued at more than 1 US$m each. In an earlier special

Figure 12. Exceptional individual stones from Karowe Mine: 203.9 ct (2014) (left) and 342 ct (2015) (right).

tender in 2013, 16 stones, totaling 1,028 ct were sold for a gross revenue of 24.7 US$m (24,026 US$/ct). The highest value stone was a 135.4 ct diamond which sold for 6.37 US$m. The company's first exceptional diamond tender earlier in that year of 15 single stones (totaling ~815 ct) fetched some 24.85 US$m or 30,468 US$/ct. The average revenue of Karowe diamonds, including the large stones, is close to 700 US$/ct.

Voorspoed (South Africa)

The Voorspoed kimberlite, located 190 km southwest of Johannesburg, was discovered in 1906 by H.S. Harger and was briefly mined until 1912 with approximately 1 Mct produced, when it closed due to poor diamond recoveries. This is now known to have been due to a combination of hard ore, inadequate diamond recovery technology and the lack of a robust geological model (Field *et al*., 2008). De Beers acquired the mine in 1912 and it re-opened in 2006. Between 2006 and 2012 some 2.6 Mct were produced from 11 Mt at an average grade of 24 cpht (De Beers annual reports).

Voorspoed is a Group 2 kimberlite which was emplaced into the Karoo Supergroup some 145 Ma ago. The pipe is oval-shaped and was 12 ha at surface, 6 ha of which was taken up by a massive raft of Stormberg basalt and associated breccias, which syn-eruptively collapsed into the pipe (Fig. 13).

The pipe infill is a combination of volcaniclastic kimberlite and probable pyroclastic kimberlite units (Stiefenhofer, 2003). However the high levels of grade and revenue variance encountered during early mining suggested that the geological model was not yet optimised and prompted a detailed groundmass geochemical study which revealed the presence of a second magma source with a distinct diamond population (Stiefenhofer, 2011 and 2013).

Historic diamond recoveries from Voorspoed were noted to be unusually hard and difficult to cut at the time (Wagner, 1914 quoted in Field *et al*., 2008). Cubic diamonds were reported, but the parcels were dominated by dodecahedral shapes. The historic production was characterised by a large proportion of coloured stones, with only rare white diamonds. Current production is dominated by colourless to near colourless stones with some yellow diamonds and a small proportion of pink diamonds. Hardly any brown stones are reported. Large stones (+10.8 ct) are recovered on a weekly basis. Voorspoed is also known for its Type II diamonds, which typically contain sulphide inclusions (De Beers unpubl. data).

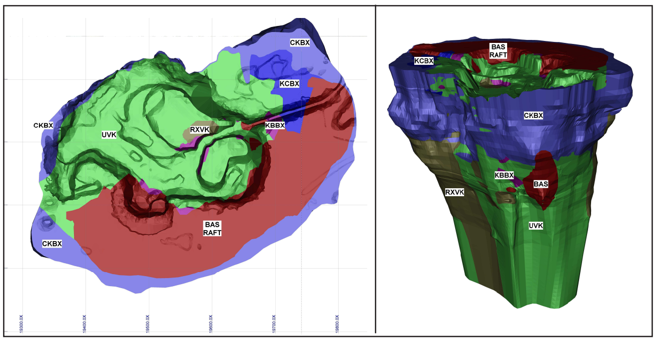

Figure 13. Geological model of the Voorspoed kimberlite with the surface expression shortly after the re-commencement of mining in 2006 (left) and with the original decline from the mining prior to 1912 still visible on the eastern side. Note the large basalt raft within the pipe in red, and varieties of kimberlite and country rock breccias in shades of blue and purple. An isometric view of the pipe is shown on the right. The model extends to a vertical depth of 624 m below surface (Courtesy DBCM). BAS = basalt, VK = volcaniclastic kimberlite, CKBX = kimberlite country rock breccia, KBBX = kimberlite basalt breccia.

Letlhakane (Botswana)

The Letlhakane pipes DK1 (13 ha) and DK2 (2.2 ha) lie within the Orapa kimberlite province. They were discovered in 1970 by De Beers and brought into production in 1975 and 2007 respectively. The age of these pipes is presumed to be the same as that of the AK01 (Orapa Mine) at 93.1 Ma. From 1975 up to 2014 the mine produced roughly 31 Mct from almost 110 Mt (29 cpht) (Debswana, MA Roberts, pers. comm., 2015). The DK1 pipe consists of volcaniclastic kimberlite, of which there are at least two main types (VK1, VK2,) and macrocrystic kimberlite which is a type of coherent kimberlite (Fig. 14).

The DK2 pipe comprises a complex association of massive volcaniclastic kimberlite (VK1, VK2, VK3 and VK5), macrocrystic kimberlite and associated lithic-rich basalt and country-rock breccias. The macrocrystic kimberlite is the dominant pipe infill, with the various volcaniclastic kimberlite deposits forming marginal sub-ordinate domains. A similar emplacement mechanism is inferred for both pipes, with a complex series of volcanic eruptions resulting in pipe excavation and infill by kimberlite with a variety of textures.

The DK1 open pit closed in 2014 when the bottom of Cut 4 was reached at a depth of 350 m (Fig. 14), with the focus shifting to the mining of coarse tailings and possibly an underground mine in the future. Current mining activities are limited to the smaller DK2 kimberlite with the Cut 3 operation planned for completion in 2016. Recent production averages 2 Mt of ore per annum generating ±0.45 Mct/a. Future exploitation of the Letlhakane Tailings Mineral Resource will extend the life of mine to around 2042 producing ±0.8 Mct/a. The probable reserves of these tailings are 34.9 Mt containing 8.9 Mct at an average grade of 25.4 cpht (Anglo American Corporation, 2013).

Tier-3 diamond mines

Tier-3 mines are those deposits that produce or have the demonstrated potential to produce between 0.05 Mct and 0.4 Mct/a over a minimum period of five years (Fig. 15). Historical mines such as Jagersfontein and Dokolwayo that are now depleted and/or dormant, have been included in the list but not in the resource tables.

This category also includes projects for which the resource information is limited, such as some of the Angolan kimberlites (Table 3).

South Africa

Kimberley underground mines

The Kimberley Mines consist of the Kimberley (Big Hole), De Beers, Dutoitspan, Bultfontein and Wesselton kimberlite pipes (Table 3). Only Dutoitspan, Bultfontein and Wesselton, the Kimberley

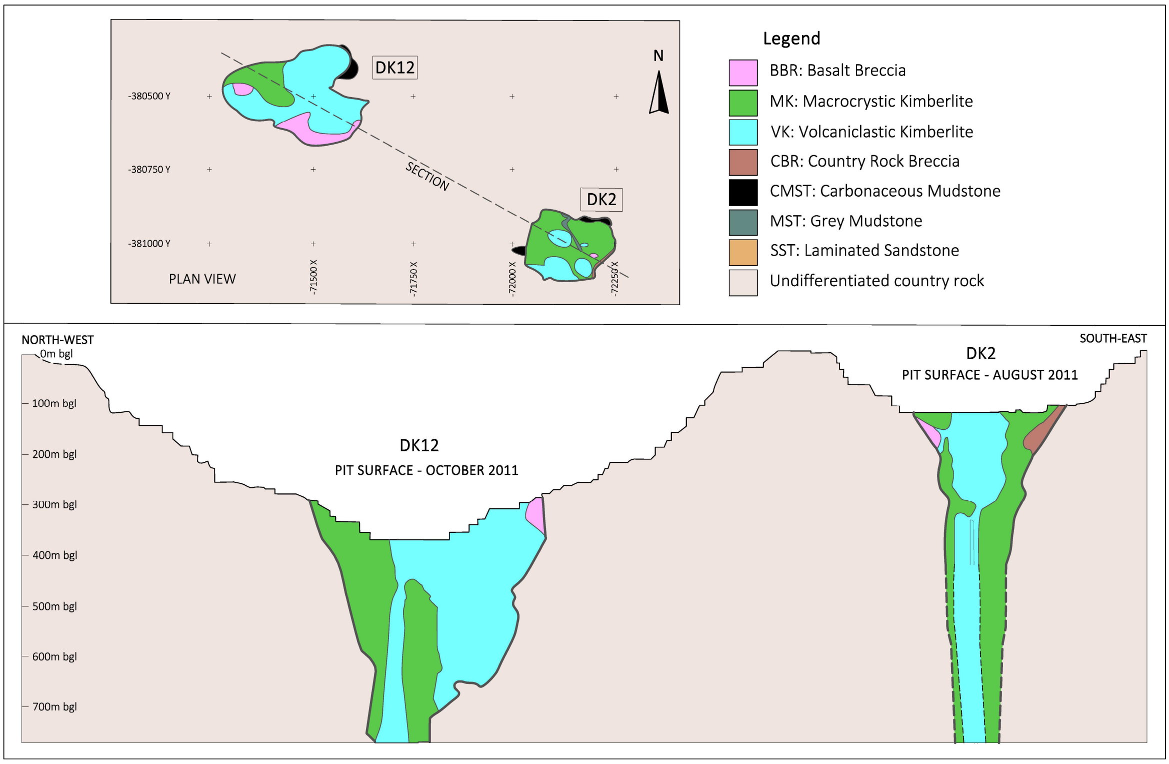

Figure 14. Schematic geological section (N-S) of Lethlakane Mine with outlines of the current open pit (Courtesy Debswana).

Underground Mines (KUM), are presently producing as underground mines (Fig. 16).

Dutoitspan and Bultfontein were discovered in September and December of 1870, followed by the De Beers and Kimberley mines in May and July of 1871 respectively and eventually Wesselton in September 1890 (Davenport, 2013). The mines were initially subdivided into individual claims (±100 m² each), which led to chaotic mining. It was Cecil John Rhodes who was largely responsible for consolidating the claims, after he had gained control of the Kimberley, De Beers, Bultfontein and Dutoitspan mines and ended up forming the DBCM (De Beers Consolidated Mines Ltd.) in 1888. DBCM then acquired Wesselton Mine in 1891.

The pipes were mined as open pits to approximately 100 m. The Kimberley and De Beers Mines became underground mines in 1884. The Kimberley Mine was mined to a depth of 820 m and was closed in 1914 whilst the De Beers Mine closed in 1991. The others were put on care and maintenance by De Beers in 2005, but were re-opened after being acquired by Petra Diamonds in 2009.

The Kimberley pipes produced approximately 182 Mct in total of which the Kimberley Mine produced over 14 Mct from 22.6 Mt of kimberlite. The pipes have a history of producing large diamonds and fancy yellows, such as the 253 ct Oppenheimer diamond produced from Dutoitspan in 1964. All three currently operating mines produce high quality diamonds with values in excess of 300 US$/ct (Petra Diamonds, 2014d).

The kimberlites have intruded flat lying sediments of the Lower Karoo Supergroup (Permo-Carboniferous), intruded by dolerite sills of up to 40 m thick, overlying Archaean Ventersdorp Supergroup lavas and meta-sediments and basement granites.

The pipes are all Group 1 kimberlites and form part of a cluster of close to 30 known kimberlites within a 10 km radius around Kimberley. Many of the pipes have been mined to some extent.

The Wesselton pipe is composed mostly of pyroclastic kimberlite breccias, cut by late-stage dykes. The process of multiple intrusions of kimberlite has resulted in large wedges of barren country rock within and between phases of the kimberlite. The Dutoitspan kimberlite is geologically complex with 18 different kimberlite phases recognised (D1-D18). The Bultfontein pipe has at least three major phases of kimberlite intrusions within the carrot shaped, oval pipe (Clement 1982).

De Beers is presently mining the Kimberley tailings, a resource of some 32 Mt at an average grade of 3.9 cpht (Anglo American Corporation, 2013) but have sold these recently to Ekapa Minerals.

Koffiefontein

The first diamonds beyond the river diggings were found in July 1870 and led to the discovery of the Koffiefontein pipe, located about 105 km southeast of Kimberley. In 1892 Koffiefontein Mining Company Ltd., consolidated the individual claims to form an open cast mining operation and in 1911 these were ceded to De Beers Consolidated Mines Ltd. Mining ceased in 1932 and only resumed in 1971. The mine went underground in 1981 and in 2007 the mine was acquired by Petra Diamonds Ltd.

The pipe intruded Archaean granite-gneiss and approximately 250 m of overlying sediments and dolerites of the Karoo Supergroup. The presence of Karoo xenoliths within the kimberlite pipe indicate that a large part of the Karoo sequence was present at the time of emplacement.

The Koffiefontein pipe is the largest and most economic of a cluster of three Group 1 kimberlites, the others being Ebenhaezer and Klipfontein. These lie on a northwest orientated structure and are thought to be linked to a single dyke at depth (Wagner, 1914). The area of the pipe at surface was approximately 11.1 ha. It is

Table 3. Tier-3 deposits: Medium size mines

Tier-3 Diamond mines in Africa (+0.05 to -0.4 Mct/a): Resources – Indicated and inferred resources (incl. reserves)										
Mine	Discovered/ Discoverer	Age (Ma)	Group	Ha	Tonnes (Mt)	Grade (cpht)	Contained diamonds (Mct)	Cut-off (mm)	LOM (yrs)	Mct/a
Kimberley° (RSA) (Bultfontein, Dutoitspan, Wesselton)	1870 1870 1890	84 (78 to 92)	1	29.2 (3x)	65.9	9.7	6.41	0.5 and 1; Reserves 1.5	8 (UG)	0.14
Koffiefontein° (RSA)	1870	90	1	11.1	154.6	4.3	6.65	0.5 and 1; Reserves 1.5	11 (UG)	0.07
Letseng[+] (Lesotho)	1957 Nixon	94.6	1	20.6 (2x)	293.9	1.70	5.03	2.00		0.09
Kao (Lesotho)[6]	1954 Diggers	83	1	19	183.4	6.36	11.66	1.00 to 2.00	21	0.12
Lemphane[2] (Lesotho)	1957 Jack Scott		1	6	46	2	0.92	2.00?	10 (OP)	0.07
Damtshaa* (Botswana)	1967 De Beers	93?	1	13.5 (2x)	49.5	21.5	11.2	1.65	19 (OP)	0.19 (2012)
Leralat (Botswana)	1991 De Beers	1,364	1	6.2 (5x)	12.2	25.5	3.1	1.00	7	0.4
Mwadui° (Tanzania)	1940 Williamson	52	1	146	1016.1	3.3	33.10	1.15	20	0.19
Camutue W (Angola)	1958	120?	1	9	9 (to 150 m)	9.6				0.15
Camatchia (Angola)	1955	120?	1	29.4	120 (to 400 m)	8	0.96			0.17
Camagico (Angola)	1966 Diamang	120?	1	23		30				
Koidu K1 (Sierra Leone)	1930	146	1	0.45	5.0	67	3.31	300 – 400 US$/ct	5 (OP) 12 (UG)	0.35
Koidu K2 (Sierra Leone)				0.5	4.4	33	1.45			
Baoulé/K23[5] (Guinea)	1999		1	5	22.2	15	3.3 Mct (300 m)	1.25; 200 US$/ct	10	0.3
Camafuca C[3] (Angola)	1952	120?	1	160	23.3	5	1.15			
Mothae (Lesotho)	1961 Jack Scott		1	8.8	39.0	2.7	1.06	2.00	Care & Maintenance	
BK11 (Botswana)	1974 De Beers	93?	1	8					Care & Maintenance	
Jagersfontein (RSA)	1870		1	12			Closed in 1971			
Dokolwayo (Swaziland)	1975 De Beers	203	2	2.8			Closed in 1996			0.04 - 0.07
River Ranch (Zimbabwe)	1975 De Beers	519?	1	5.2		30	Closed in 1996 and 2012			0.4
Total					**2044.5**	**15.4**	**89.3**			**2.24**

°Petra Diamonds Resources and Reserves at Cullinan June 2013. *Anglo American Ore Reserves and Mineral Resources report 2013. [2]Paragon Press release June 2014. [3]Southern Era 2000. [4]Kimberley Diamonds Ltd August 2014. [5]Investors Presentation Stellar Diamonds Q4 2014. [6]Namakwa Annual report 2012.

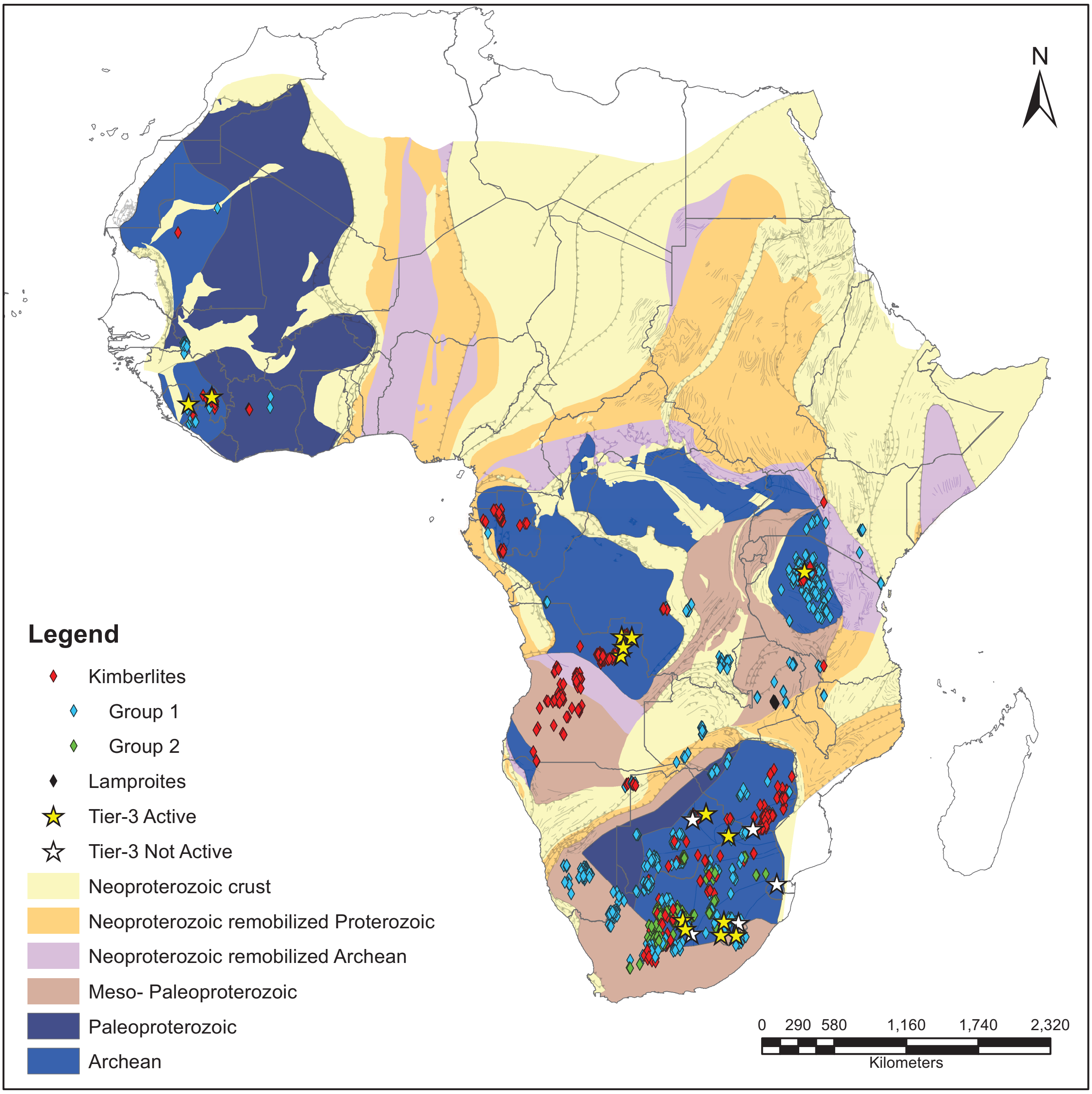

Figure 15. Geological map of the Precambrian basement of Africa (de Wit and Linol, 2015) with known Group 1 (red) and Group 2 (blue) kimberlites, and lamproites (purple), highlighting Tier-3 diamond deposits.

steep-sided and narrows down to 7.8 ha at 490 m below surface.

The internal geology of the pipe is complex and eight kimberlite phases have been recognised. In addition there are down-rafted blocks of Karoo sediments, dolerite and crater facies material (Naidoo *et al*., 2004). Two coherent-transitional kimberlite precursors, referred to as the East and West fissures, flank the main pipe.

The development of three new production levels is at an advanced stage, with production planned to gradually ramp up to 1.1 Mt (0.11 Mct) by 2017 and it is contemplated to mine down to 720 m. The mine is a regular producer of Type II diamonds with occasional high value fancy pinks; run of mine diamond values are in excess of 800 US$/ct (Petra Diamonds, 2014c). The current resources are listed in Table 3. The mine has produced some 9 Mct from 113 Mt (8 cpht) up to 2014 (De Beers and Petra Diamonds annual reports).

Jagersfontein

Located some 56 km southeast of Koffiefontein (Fig. 15), diamonds were first discovered at Jagersfontein in August 1870. Now recognized as the deepest hand-dug (~200 m) hole on Earth, Jagersfontein was the second kimberlite mine to operate in South Africa. Interrupted only by the two World Wars and the Great Depression, open-pit mining moved, by the sinking of a shaft in 1910, to an underground operation that continued until its eventual closure in 1971.

The main pipe, one of seven kimberlites in the cluster, is 12 ha on surface and has intruded sedimentary rocks of the Karoo Supergroup and a thick dolerite sill of some 245 m in thickness. With an intrusion age of 85 Ma the body is a classic Group 1 kimberlite. It is estimated

Table 4. Summary of the Kimberley Mines

Mine	Discovered	Surface area	Historical Grades	Depth of mining	Internal geology
Dutoitspan	1870	10.8	32	755 m level	18 kimberlite phases (D1- D18)
Bultfontein	1870	9.7	54	845 m level	At least 3 kimberlite phases (B1- B3)
De Beers	1871	5.1	72	785 m level	6 Different kimberlite phases (DB1-DB6)
Kimberley	1871	3.7	200	820 m level	
Wesselton	1890	8.7	37	995 m level	10 different kimberlite phases (W1- W10)

that between 0.5 and 1 km of post-emplacement erosion has occurred (Hanson, 2009) and the kimberlite grades downwards from diatreme to hypabyssal facies. Blocks of crater facies kimberlite from higher levels have been down-rafted into the diatreme.

Although the overall grade of diamonds was low (8-10 cpht), the diamonds were generally recognized as "superior" in quality and in size. Diamonds of exceptional quality, "blue-whites" were known as *Jagers*. The Excelsior at 995.2 ct remains the second largest diamond ever reported (Fig. 17) and along with stones in the 300-600 ct range (the Reitz was 650.8 ct), puts Jagersfontein along with Cullinan, Karowe and Letšeng, as mines famous for large, high quality stones. Approximately 9.6 Mct (1,900 kg) of gem-quality diamonds were extracted during the life time of the mine. The diamonds currently retrieved from the reworking of the tailings, (some 57 Mt at 12.5 cpht (*www.miningmx.com 2011*)), are small in size but of high quality.

Jagersfontein contains xenoliths from 300-500 km depth, which contain majoritic garnet, and these continue to hold the global record for the deepest rocks (not diamonds) known to have reached the Earth's surface (Haggerty, pers. comm., 2014).

Lesotho

Kimberlites were first recorded in Lesotho by Stockley (1947). In the 1960s and 1970s Leeds University researchers, Basutoland Diamonds Limited (BDL) and the United Nations Development Programme (UNDP) increased the number of kimberlites to 249 (UNDP, 1974). The most important of these are Letšeng-la-Terai ("Letšeng"), Kao, Liqhobong and Lemphane (Fig. 10). These pipes were declared government diggings, and by 1967 there were up to 6,000 local diggers at Letšeng who, between 1959 and 1967, produced some 63,000 ct including the 601 ct Lesotho Brown diamond (UNDP, 1981).

Historically only the Letšeng and Liqhobong pipes were mined. However in recent years Mothae, Kao, Lemphane and the Motete Dyke have been evaluated. Other kimberlites include the 1.2 ha Kolo kimberlite situated approximately 40 km southwest of Maseru, which produced 1,310 ct from 11,938 t of kimberlite at an average grade of 11 cpht (Thabex, 2009). Another is Pipe 200, which is a small irregular kimberlite pipe measuring approximately 1 ha in extent. It was bulk sampled between 1972 and 1973 (UNDP, 1974) and reported 5.14 ct from 250 t of kimberlite treated.

Lesotho is situated on the southern edge of the Kaapvaal Craton which, in Lesotho, is covered by some 4 km of the flat-lying Palaeozoic to Mesozoic Karoo Supergroup sediments and Jurassic basalts. The Lesotho lowlands have experienced at least 1,800 m of erosion since the time of kimberlite emplacement (90-95 Ma), whilst the pipes occurring in the highlands, containing predominantly volcaniclastic kimberlite, are better preserved.

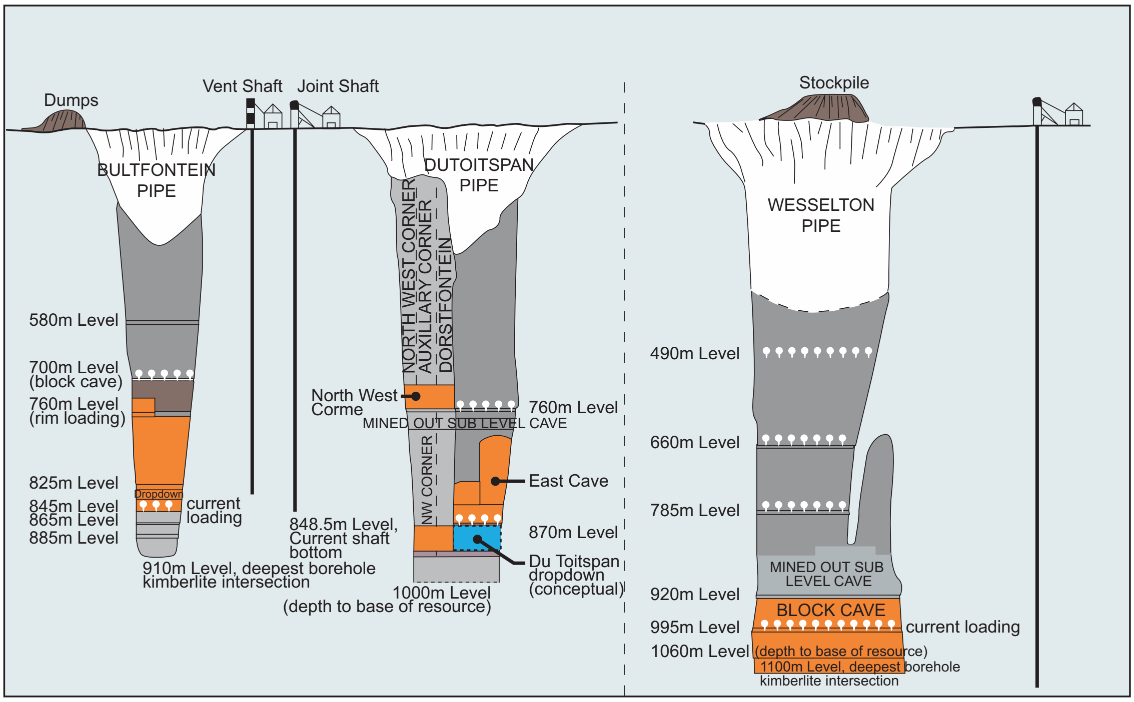

Figure 16. Schematic sections of Bultfontein, Dutiotspan and Wesselton Mines in Kimberley (Courtesy Petra Diamonds).

Figure 17. The Excelsior 995.2 ct diamond was cut into 11 pieces of 10 ct to 70 ct each and the 70 ct pear-shaped Excelsior 1 (top, photo De Beers) was set into a bracelet by Mouawad (bottom).

Letšeng

Letšeng comprises two adjacent pipes (the Main - 15.9 ha and the Satellite pipe - 4.7 ha) and lies at an elevation of approximately 3,100 m. It was discovered by PH Nixon in 1957 during a research project, as a weathered outcrop in a stream. Rio Tinto Exploration (Pty) Ltd. initially evaluated the pipes between 1968 and 1972 but abandoned the project mainly because of the low grade (<4cpht). Thereafter De Beers re-evaluated the kimberlites and eight varieties of kimberlite were recognised in the Main Pipe. However, only K6 was considered economic at the time. K6 is a later stage diatreme that cuts through all the other units except K5. De Beers operated the Letšeng Mine on the K6 unit of the Main Pipe from 1977 to 1982 producing 0.27 Mct at an average grade of 2.9 cpht.

Production on the limited alluvial deposits re-started in 2003 and mining of the kimberlites in 2004. Gem Diamonds Ltd. acquired Letšeng in 2006 and operates the mine in partnership with the Government of Lesotho (30%).

The mine is famous for producing exceptionally large, high value diamonds (many of them nitrogen-free Type IIa diamonds), and obtained an average price of 2,688 US$/ct in H1 2014 which is the highest average revenue per carat of any kimberlite mine in the world.

Letšeng produced 0.74 Mct from 48.2 Mt at an average grade of 1.54 cpht between 2006 and 2013. The recovery of 35 diamonds over 100 ct during that period gave a yield of approximately one plus 100 ct stone every 1.3 Mt of kimberlite processed.

Kao

The Kao kimberlite pipe is Lesotho’s largest diamond-bearing pipe and the fourth largest in southern Africa (19.8 ha). The pipe comprises six principal facies of volcaniclastic and reworked volcaniclastic kimberlite types, the earliest of which (K6 or Quarry) has the highest grade at some 16-19 cpht, whereas the other facies have lower grades ranging between 4.7 and 6.7 cpht. Overall, the diamond quality runs at approximately 65% Gem, 8% Near Gem and 27% Rejections. The Main Pipe is being developed as an open cast mine with a potential life of approximately 20 years.

In 2012 some 0.12 Mct were recovered from 1.1 Mt of kimberlite at an average grade of 10.8 cpht, including individual stones of 82 ct, 72 ct and 60 ct, as well as three 50 ct stones. The largest unbroken gem recovered to date is a 112.96 ct Type IIa white stone whereas the highest value stone found to date is a 36.02 ct Type IIa pink diamond. In addition, a broken 131.72 ct near-gem white stone (fragments of 88.6 ct and 43.12 ct) was recovered. A 1.61 ct pink stone recovered in September 2012 realised 50,311 US$/ct (Namakwa Diamonds annual report, 2012). The average value in 2012 was 201 US$/ct (Table 3).

Mothae

The Mothae kimberlite consists of a main South Lobe connected to a smaller North Lobe by an elongate central kimberlite breccia body. The South Lobe contains the best grades and has a surface expression of 5.1 ha. The three areas combined form a total surface area of 8.8 ha. The contact between the kimberlite and the basalt is typically sharp and steep with localized zones of wall rock breccia.

The mineral resource estimate for Mothae is based on a bulk sampling programme conducted between 2008 and 2010 by Lucara Diamond Corp, in which a total of 0.61 Mt was processed, yielding a total of 0.24 Mct of diamonds at 3.9 cpht, including a broken yellow octahedron of approximately 82.3 ct. Whilst the size frequency distribution reported at Mothae is comparable (though not identical) to Letšeng, the total sample was not sufficient to recover a representative selection of very large stones, including stones over 100 ct. The indicated mineral resource down to 50 m is 2.39 Mt at 3.2 cpht and 931 US$/ct (Lynn *et al*., 2013; Nowicki, 2014) and the mineral resource to 300 m is listed in Table 3.

Lucara has placed the Mothae Project under care and maintenance pending a decision on whether to proceed with the project or not.

Lemphane

The Lemphane kimberlite consists of a single oval pipe of approximately 6 ha in extent. The internal geology has been outlined by ground magnetic surveys, mapping and limited core drilling, and suggests that the pipe comprises three main domains: Northern, Southern and ‘Satellite’(part of the main pipe and thought to be an early blow on a dyke, which was subsequently mostly removed by the emplacement of the intrusion of the main pipe). The results from roughly 0.02 Mt as part of a preliminary bulk sampling program indicate an average sample grade of approximately 2 cpht (Lynn 2013).

Swaziland

Dokolwayo

In 1973 De Beers discovered the diamondiferous upper Triassic grits and conglomerates (Karoo Supergroup) at Hlane in northeastern Swaziland. Sedimentological studies (Turner and Minter, 1985) lead the company to the Dokolwayo kimberlite some 30 km west of Hlane in 1975. This diatreme has intruded late Archaean granite-gneisses. The kimberlite contains numerous xenoliths of sedimentary rocks including coals of predominantly Permian age. Apart from dykes and minor dyke enlargements, no other diamondiferous kimberlites have been found between Hlane and Dokolwayo. This suggests that the diamonds in the sediments were derived from Dokolwayo which must have been emplaced sometime between the Permian and Triassic (Hawthorne *et al*., 1982). This was later confirmed as 203 Ma (Allsopp and Roddick, 1984).

The Dokolwayo diatreme is elongate and has an irregular outline. It measures 2.8 ha at surface and increases to 3.4 ha at a depth of 50 m. Transhex operated the mine from 1984 to 1996 and produced between 42,500 ct/a and 76,100 ct/a (Coakley, 1996). Efforts were underway in 2011 to re-open the mine but so far there has been no significant production.

Botswana

Damtshaa

The four pipes that make up the Damtshaa Mine are BK01 (5.5 ha), BK09 (10.3 ha), BK12 (3.2 ha) and BK15 (3 ha), which occur some 18 km east of Orapa Mine. The BK01 pipe was the very first kimberlite discovered in Botswana in 1967. The Damtshaa Mine opened in 2002 initially focussing on the two largest bodies BK09 and BK12 (Fig.18) and by 2014 it had produced roughly 2.8 Mct from nearly 15 Mt of ore at a grade of just over 20 cpht (Debswana, M.A. Roberts, pers. comm., 2015). The BK09 kimberlite has been dated (Rb/Sr) at 99 ± 3 Ma (Barton and Smith, 1995), with the adjacent BK12 pipe assumed to be of a similar age. Figure 18 below shows a schematic geological cross - section (north-south) across the two kimberlite pipes.

BK09 consists of at least two coalesced kimberlite pipes. Epiclastic kimberlite dominated the upper geology prior to the onset of mining activities and is underlain by a complex set of volcaniclastic kimberlite and hypabyssal kimberlite units. As is the case with BK09, the upper portion of BK12 is dominated by sedimentary kimberlite infill with the underlying material being volcaniclastic and pyroclastic kimberlite. Currently ~1.5 Mt/a of ore is being mined generating ~ 0.40 Mct/a. Life of mine will potentially extend to 2030 and is it estimated to produce some 5 Mct during that period from 39 Mt at an average grade of 16.6 cpht.

The BK11 pipe

BK11 was found in 1974 by De Beers and has a surface expression of 8 ha. It lies 5 km northeast of the Karowe Mine. Firestone Diamonds started an evaluation program in 2007 and commenced trial mining in 2010 after defining a resource to 120 m of 11 Mt at a grade of 8.5 cpht (MPH Consulting Ltd in Firestone annual report 2011). The initial mining took place on the western part of the body where an estimated 5.4 Mt of kimberlite with a grade of 12.6 cpht was identified. A total of 0.016 Mct were recovered from 0.8 Mt of kimberlite at an average grade of 2 cpht, during 2011 and 2012. The mine was put on care and maintenance in 2012.

Lerala Diamond Mine

The Lerala Diamond mine was found by De Beers in 1991 in eastern Botswana and consists of eight kimberlite pipes, five of which are diamondiferous (K2 -K6). The total surface area of these pipes is 6.2 ha. The indicated resource at a cut-off size of 1 mm, is 12.2 Mt at an average grade of 25.5 cpht, ranging from 20.6 cpht for K5 to 31.0 cpht for K6, resulting in 3.1 Mct at an average value of

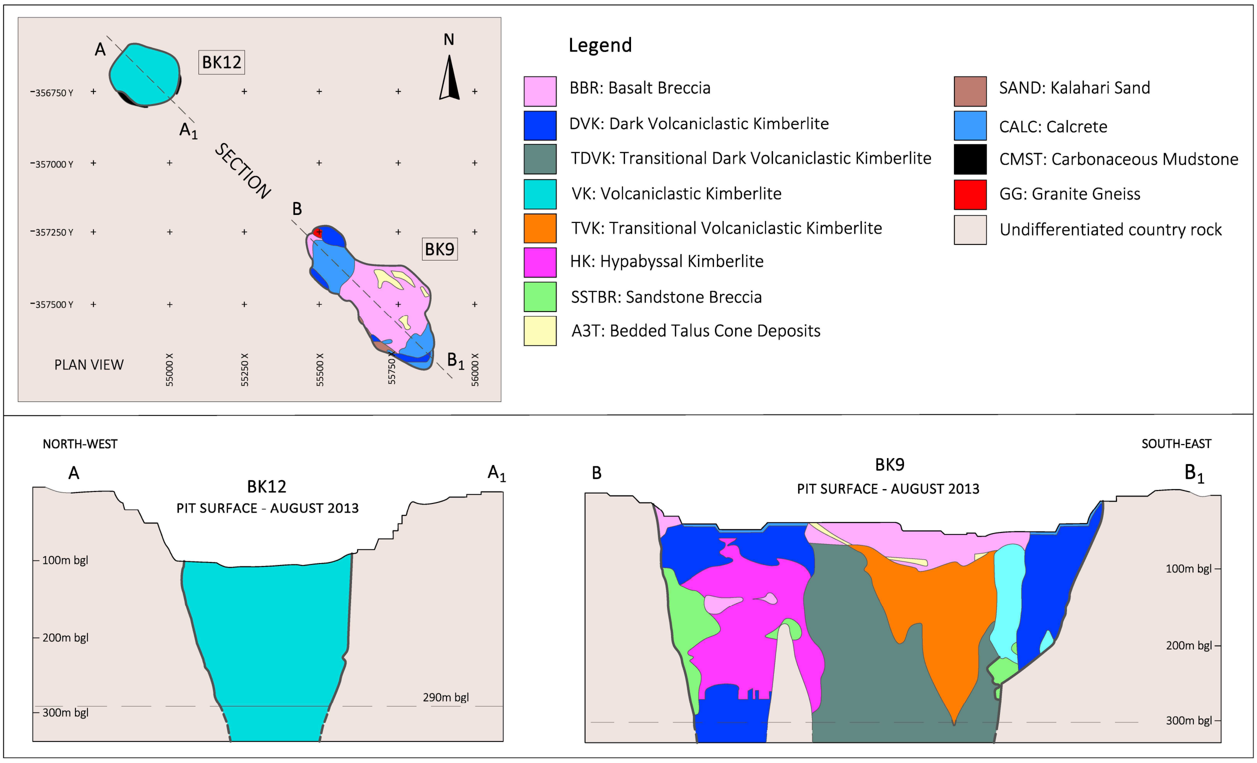

Figure 18. Schematic geological section (N-S) of BK09 and BK12 kimberlite pipes which forms part of the Damtshaa Mine, with the outlines of the current open pit (Courtesy Debswana).

55 US$/ct (Kimberley Diamonds Ltd., 2014). These bodies have been dated at 1364 Ma (Woodhead *et al*., 2009). The kimberlites were subjected to limited mining by DiamondEx Ltd in 2008 and Mantle Diamonds in 2012. Kimberley Diamonds Ltd. is re-commissioning the mine which is expected to re-open in H2 2015.

Zimbabwe

River Ranch Diamond Mine

The River Ranch Group 1 kimberlite was discovered by De Beers in 1975 and is part of a cluster of four kimberlites which lie some 12 km northwest of Beitbridge. The pipe is 5.2 ha at surface and has vertical contacts to at least 70 m below surface. There are two small root zone kimberlites to the east and a small kimberlite body to the southwest (Kopylova *et al*., 1997). The pipe is situated in the Central Zone of the Limpopo Mobile Belt and intrudes Archaean metasediments of the Beitbridge Group.

The erosion level of the kimberlite indicates that most of the diatreme was removed and the present level is between the diatreme and root zones. The presence of essentially three main kimberlite types, namely tuffisitic kimberlite (volcaniclastic kimberlite), tuffisitic kimberlite breccia (massive volcaniclastic kimberlite) and hypabyssal kimberlite (coherent kimberlite) support this and at least seven different phases of intrusion have been recognised (Kopylova *et al*., 1997). The pipe is broadly similar to Venetia and is probably also Cambrian in age (Muusha and Kopylova, 1999).

De Beers evaluated the River Ranch kimberlite in 1975 but failed to acquire the mining rights. Auridium (Pty) Ltd and Redaurum Ltd then developed the mine between 1991 and 1994. Although little has been officially published, the grade of the kimberlite is thought to average 30 cpht and the diamonds are reportedly of relatively low value, averaging around 30 US$/ct (Mobbs, 2009).

The mine produced 0.47 Mct in the first full year of production (1996), but due to low diamond value it was closed in 1998. It was resuscitated from 2006 to 2012 by local Zimbabwean operators and although little is known about recent operations it was reported to have produced 0.08 Mct in 2009 (Partnership Africa Canada, 2010).

Tanzania

Mwadui

The Williamson Diamond mine is located on the Mwadui kimberlite pipe approximately 130 km southeast of Mwanza in Tanzania (Edwards and Howkins, 1966). It was discovered by Canadian geologist Dr. John Williamson in 1940 and developed and managed by him until his death in 1958. The mine was sold to a De Beers/Tanganyika government partnership in 1958 and was operated by De Beers until 1973. The State Mining Corporation (Stamico) then operated the mine until 1994 after which De Beers returned, recapitalizing the mine and continued as operator until the mine was acquired by Petra Diamonds in 2009. During this time and as the open pit progressed into primary kimberlite, just under 3 Mct were produced from 46 Mt (1997 to 2014, De Beers' and Petra's annual reports) and the grade steadily dropped from around 20 to 5 cpht.

The Mwadui pipe is 146 ha in surface area making it the world's largest producing diamond mine in terms of area and has been dated at 52 Ma (Stiefenhofer and Farrow, 2004). The pipe was emplaced in Archaean granitic basement and Nyanzian age meta-sediments. The Mwadui kimberlite is one of over 360 pipes that were emplaced into the Tanzanian craton (Stiefenhofer and Farrow, 2004). The kimberlitic crater deposits comprise various forms of re-sedimented volcaniclastic kimberlite (Fig. 19). Granite breccias are found along the crater edge and are often silicified. Breccias also occur as debris flow and avalanche deposits, occasionally interbedded with the other crater units at the base of the crater.

In the pipe, the granite breccias (GB) grade into brecciated volcaniclastic kimberlite (brecciated volcaniclastic kimberlite) and re-sedimented volcaniclastic kimberlite respectively. These volcaniclastic units occur beneath a finer-grained turbidite sequence that resembles sedimentary Bouma sequences (Fig. 19). Overlying the turbidites is the shale basin representing the final stages of crater infill. Early Eocene plant fossils have been recovered from the crater sediments indicative of a sparse palynoflora of low diversity (Cantrill *et al*., 2013). Underlying the crater facies is the diatreme with

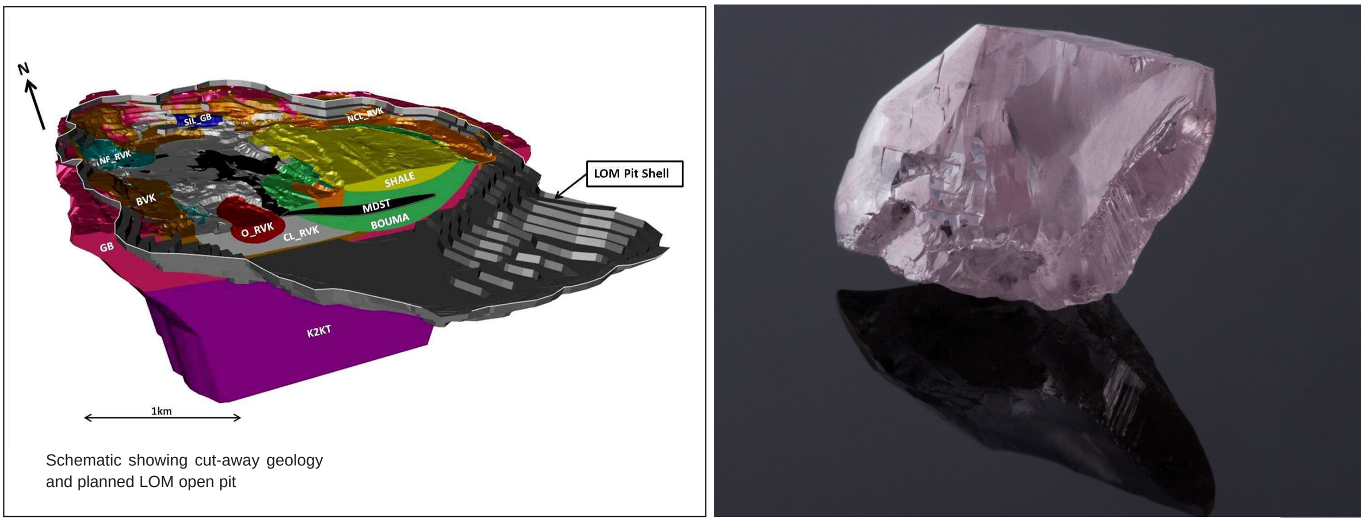

Figure 19. Geology and open pit of the Williamson Mine in Tanzania (left) showing relative positions of GB (granite breccia), BVK (brecciated volcaniclastic kimberlite), RVK (re-sedimented volcaniclastic kimberlite) (Courtesy Petra Diamonds). (right) The 16.39 carat pink diamond recovered by Petra Diamonds in 2014 (photo Petra Diamonds).

pyroclastic kimberlite. These facies extend to at least 680 m below surface.

The current resource statement of the Williamson Mine is based on a combination of historical and current data (Table 3). The open pit operation is currently at a depth of 85 m. Recent production has reached 3.5 Mt/a, but plans are in place to increase this to 5 Mt/a. The current life of the mine extends to 2033. Diamonds include rounded white diamonds and high quality fancy pinks which in 2014, fetched an average value of 307 US$/ct. The Williamson Pink, a 54 ct stone found in 1947, is considered the finest pink diamond ever discovered. It was cut into a 23 ct stone and set in a brooch for the Queen of England. More recently another stunning 16.39 ct pink diamond was recovered at the mine (Fig. 19).

Angola

Diamonds were first recovered in Angola in 1912, from a tributary of the Chiumbe River by Forminière, who were tracing the source of diamonds found in the Tshikapa area, in what was then the Belgian Congo.

A prospecting company called PEMA (Companhia de Pesquisa Mineira de Angola) was set up in 1912 and in 1917 the Portuguese parastatal DIAMANG was formed to mine the alluvial deposits. DIAMANG was largely nationalized and in 1986 it was replaced by a new state mining company called ENDIAMA (Empresa Nacional de Prospecção, Exploração, Lapidação e Comercialização de Diamantes de **Angola)**.

In 1952 Camafuca-Camazamba (Lunda North Province) was the first kimberlite to be discovered in Angola and a further 450 kimberlites were found between 1952 and 1975. After the introduction of a new mining code in 2002, kimberlite exploration experienced a boom with an estimated 500 additional kimberlites being discovered, concurrently there was a decline in production from some of the major alluvial diamond mines such as Calonda, Mafuto, Lucapa and Luzamba.

Over the period 1917 to 2013 Angola produced 193 Mct, of which 92 Mct (48%) came from alluvial mining, 23 Mct (12%) from artisanal diggings and almost 77 Mct (40%) from kimberlites (Chambel, 2013) (Table 6). Most of the kimberlite production viz. 75 Mct (38% of the total) was mined from Catoca with a minor contribution of 2.8 Mct (2.5%) from other kimberlites (Camatchia and Camútue).

In northeast Angola, production from large-scale alluvial operations in the Chicapa, Luachimo and Luembe Valleys, has remained at between 0.25 and 0.30 Mct/a, and in the Cuango Valley around Luzamba and Cafunfo, between 0.40 and 0.70 Kct/a (Kennedy, 2008).

Camutue West

The Camutue West kimberlite was discovered in 1958 and falls within the Camutue cluster of seven occurrences including the Camutue East and Caixepa pipes.

The pipe has an oval shape of 550 x 450 m and measures 9 ha. At a depth of some 120 m the size of the pipe decreases significantly. The upper crater part of the pipe is filled with re-sedimented volcaniclastic kimberlite, and pyroclastic kimberlite underlies this in the narrow diatreme.

During the mining operation between 1961 and 1974, some 3.5 Mt of material was treated with a recovery of 0.33 Mct at an average grade of between 8 and 9 cpht. The average stone size was 0.70 ct/st and the largest diamond recovered was 95.41 ct. The stone values have always been noted to be the highest of the kimberlites in Angola and have been estimated to be around 326 US$/ct (Catoca annual report, 2012). Recently CAD (Camutue Diamond Deposits sarl) mined 0.52 Mt of ore and produced 0.015 Mct with an average stone size of 0.78 ct/st and a price of 595 US$/ct and current production is estimated at 0.012 Mct per month from 0.13 Mt or around 9.6 cpht (Bloomberg press release, October 2013).

The resource is estimated at 9 Mt to a depth of approximately 115 m and the pit is currently 45 m deep. The age of the kimberlite has been put at between 120 and 130 Ma based on similarities with Catoca.

Camatchia

The Camatchia kimberlite is the largest kimberlite within the Luo Cluster which comprises seven pipes and dykes. The Camatchia pipe was discovered by DIAMANG in 1969. The pipe is located close to the confluence of the Luo and Chicapa Rivers, 65 km south-southwest of Lucapa.

The Camatchia pipe measures 680 x 520 m, is elongated in a northeasterly direction and has a surface area of 29.4 ha. The pipe splits into two bodies at a depth of 300 m. The southwestern lobe is the oldest and has pyroclastic kimberlite near surface. The northeastern lobe preserves the younger crater sediments. At the base of the crater and at the point where the two pipes coalesce, is a prominent breccia unit. The grades are variable between the different geological units. The less diluted re-sedimented volcaniclastic kimberlite in the northeastern lobe has been mined since 2005 and the grades are in the order of 8 cpht, with diamond values of around 250 US$/ct. The pyroclastic kimberlite is of higher grade, on average 25 cpht, however, this unit requires blasting and diamond values are lower at 130 US$/ct.

From 2005 to 2012 the mine produced 1.25 Mct valued at 252 US$m (200 US$/ct) and in 2012 the production of 0.17 Mct was valued at 41.5 US$m (Catoca annual report, 2012), which yielded an average price of 241 US$/ct. The resource is estimated to be 120 Mt to a depth of 400 m.

Table 5. Angolan diamond production 1917 to 2013 in Mct.

Year	Period	Artisanal	Alluvial Mines	Kimberlite Mines	Total	Average Mct/a
1917 to 1975	Colonial period	-	46.2	0.4	46.6	0.99
1976 to 1997	Civil war	8.0	24.4	-	32.4	
1998 to 2013	Kimberlite era	15.2	21.4	77.4	114.0	7.60
Total		**23.2**	**92.0**	**77.8**	**193.0**	**2.01**

Camagico

The Camagico kimberlite is also part of the Luo kimberlite cluster and occurs 5 km south of the Camatchia pipe. The kimberlite was discovered in 1972 and the deposit was initially thought to be part of the Cretaceous Calonda Formation.

The kimberlite has intruded the Archaean basement granite gneiss and overlying Lutoe (Dwyka Group equivalent) tillites and is overlain by 20 to 40 m of younger sediments. The pipe is characterized by a crater with sandy re-sedimented volcaniclastic kimberlite and finer grained crater sediments which are either Calonda Formation or epiclastic deposits. The reworked crater sediments are underlain by primary pyroclastic facies kimberlite believed to be part of the diatreme which was intersected at depths ranging from 80 to 100 m.

The kimberlite is significantly larger than the excavated pit and its size is estimated to be 23 ha. It is elongate in shape (900 x 450 m) parallel to the northeasterly drainage. The pipe size decreases to 13 ha and 8 ha at 200 and 300 m depth respectively.

Pitting and large diameter drilling confirmed high grades of almost 30 cpht at the centre of the deposit. The rest of the crater sediments were low grade and never exploited. The underlying primary kimberlite has never been adequately sampled but initial grades from smaller samples do indicate lower grades. Based on adjusted historical data, a rough estimate of diamond value in Camagico at todays' prices would be between 160 and 180 US$/ct.

Camafuca-Camazamba

The Camafuca-Camazamba kimberlite was the first kimberlite discovered in Angola (1952). It is one of the largest mineralised kimberlites in the world at 160 ha. The kimberlite is 4 km northeast of the town of Calonda and a large portion of the pipe underlies the Chicapa River and its flood plain.

The pipe is 3.2 km in length and between 0.2 and 0.5 km wide consisting of a linear grouping of possibly five or more pipes coalescing at surface. The emplacement age is similar to most of the other kimberlites in northeastern Angola, estimated between 120 and 130 Ma. The pipe is overlain by 10 - 15 m of sand and clay. Its uppermost part has a saucer-shaped broadening with very gently sloping (3-5°) walls, grading into a cup-shaped crater with wall slope of 30-35°. The occurrence comprises a small plug of primary kimberlite in the north, grading into epiclastic kimberlitic sediments towards the south, which in turn are possibly underlain by deeper-seated pyroclastic kimberlite.

The pipe was investigated extensively by DIAMANG and SouthernEra who confirmed that the bulk of the pipe is low grade (<5 cpht). However there is a zone at the southeastern margin of the kimberlite that had elevated grades of up to 15 cpht. SouthernEra completed a pre-feasibility study in 2000 and defined an inferred resource of 23.25 Mct within 145 m of surface at an average grade of nearly 5 cpht (SouthernEra Resources Inc., 2005, p 8-9). Diamond values at the time were estimated to be between 100 and 120 US$/ct.

Sierra Leone

Koidu

At Koidu the 146 Ma (Skinner *et al.*, 2004) kimberlite cluster comprises three small pipes (all <0.5ha) and numerous kimberlite dykes. Pipe K1 is 0.45 ha on surface and has three main kimberlite types - two varieties of tuffisitic kimberlite (volcaniclastic kimberlite) and a volumetrically significant coherent kimberlite infill. Pipe K2 is a southward plunging pipe of 0.5 ha in size which has seven units of variable tuffisitic kimberlite that have been intruded by late-stage hypabyssal kimberlite material.

Octéa Mining holds a mining lease over Pipes 1 and 2 and four dyke zones and has established a resource in excess of 5 Mct at a diamond value of between 300 and 400 US$/ct (including the dyke zones). Production has increased from 0.25 Mct in 2012 to over 0.30 Mct in 2013 (www.koiduholdings.com). The remaining resource in the open pit is approximately 2 Mct and the bulk of the resource will therefore be mined from underground.

Alluvial mining in the Koidu and wider Kono area has been substantial over the decades, with some spectacular stones being recovered. The third largest diamond ever discovered, the Star of Sierra Leone at 970 ct, was recovered in the Moinde River downstream of the Koidu Mine.

Guinea

Baoulé

The Baoulé kimberlite was found in 1999 and was previously referred to as K23. It is located some 20 km west of Kérouané in the renowned Aredor diamond region of Guinea. Large diamonds of +100 ct have been recovered from the Aredor area downstream from the pipe. It is a 5 ha pipe elongated in a west-northwest direction with eastern and western lobes. Stellar Diamonds PLC has started a trial mining operation and has modelled a 22 Mt resource down to 300 m. It is using a production grade of 15 cpht and a diamond value of US$ 200 / ct. The largest diamond recovered from the initial 2,000 ct yield is a 9 ct stone. The company is looking at a 2 Mt/a operation producing between 0.3 and 0.4 Mct/a.

Tier 4: Small mines, pipes and dykes

In this summary the Tier structure has been extended down to small mines (small pipes, blows and dykes) that produce, or have produced less than 0.05 Mct/a. Many of those are marginal and have seen several closures and re-openings (Table 6).

The only small mines operating recently on a continuous basis are the Sedibeng, Star and Helam mines owned by Petra Diamonds. These three have a combined resource of some 3.2 Mt at an average grade of 167.3 cpht for a diamond content of 5.28 Mct (Table 6). The underground mine at Roberts Victor was closed after the mudrush accident in 1996 although efforts have recently been made to revive the mine. New Eland, Blaaubosch and Newlands were acquired by Dwyka Diamonds in 2005 and a start was made with mining both kimberlite and tailings associated with these mines. These mines were taken over by New Rush Diamonds Ltd., who plan to start producing some 85 Kct from Newlands and Blaauwbosch in 2016 over a life of mine of 13 years (Northland Capital, 2014).

Lesotho

The Motete Dyke occurs in the highlands of Lesotho and crops out over a horizontal distance of approximately 1.5 km at elevations

Table 6. Tier-4 deposits: Small mines including blows and dykes

Tier 4: Small mines and dykes							
Mine	Discovered	Age (Ma)	Group	Occurrence	Grade (cpht)	Comments	Production
Bellsbank° (RSA): 1. Main 2. Bobbejaan	1952 De Bruyn and Mitchell	118 ± 2.8	2	Sub-parallel dykes, blows. Bobbejaan 4,2 km. Av 0.6 m wide.	1. 70 2. 25	Sedibeng mine (Messina and Dan Carl)- 0.035 Mct in 2005.	All operated by Petra Diamonds.
Swartruggens° (RSA): 1. Main 2. Changehouse	1933	156 ± 13 142 ± 4	2	6 Dykes; Av 0.6 m wide.	1. 200 2. 20	Helam mines. Historically 0.1 Mct/a 3.86 Mt	Combined: 3.2 Mt; 5.28 Mct; 167.3 cpht.
Theunissen Gr° (RSA): 1. Star	1911	124, 135 ± 6	2	2 Dyke complexes over 4.5 km	40 – 150 (East Star dyke)	Av. 47 cm wide. 0.016 Mct (2005).	0.07 Mct/a (2012 – 2017)
Newlands (RSA)	1905	114 ± 1.6	2	5 Blows on dyke	7.5		0.003 Mct (2005)
Monastry (RSA)	1876	88	1	Pipe 0.8 ha	7 – 19	Poor quality diamonds	0.002 Mct/a (1980-83)
New Elands (RSA)	1905	127 ± 5	2	1 Pipe on 2 older dykes	34 (dyke) 10 (pipe)		0.46 Mct (total)
Loxtondal (RSA)	1965	114	2	1 Pipe 1ha, 8 dykes	7 & 30 (one dyke)		
Doornkloof- Sover (RSA)			2	Dykes extend over 4 km	20 (one dyke)		0.01 (2005)
Paardeberg (RSA)	1906	120	2	Pipe 2 ha	6	Evaluated & Trial mined Diamondcore Ltd	
Klipspringer (RSA)	1995 De Beers			4 Dykes, 2 blows	47	Mined by Mwana	0.08 (2003)
West End (RSA)	1911	119	2	Pipe 0.65 ha	9	Evaluated	
Motete (Lesotho)	2000s		1	Dyke 0.2 ha	65	LOM 3-5 yrs	1.6 Mt; 1.04 Mct
Droujba (Guinea)[2]	1960s Soviet Aid mission.	154	1	Pipe 1 ha, 12 dykes	63	Care & Maintenance Stellar Diamonds	0.96 Mt; 2.50 Mct 345 US$/ct; 0.3 Mct/a?
Katcha Dyke (Guinea)[2]	1960s Soviet Aid mission.	154	1	Dyke 5 km up to 2 m wide	140	Care & Maintenance Stellar Diamonds	0.32 Mt; 0.45 Mct 57 US$/ct
Bouro (Guinea)[2]	1944	154	1	4 Dykes (5 km)	200	Care & Maintenance Stellar Diamonds	35 US$/ct
Tongo (Sierra Leone)[2]	1930	140	1	4 Dykes, 800 m to 2.5 km long; Av 0.5 m wide	165	Feasibility Stellar Diamonds	0.9 Mt; 1.5 Mct 0.12 Mct/a
Kono (Sierra Leone)[2]	1930	146 (Koidu)	1	Several dykes: Pol-K ±2 km, Bardu ± 1.5 km	66 (Pol-K), 140 (Bardu)	Evaluation suspended. Stellar Diamonds.	
Kareevlei[4] (RSA)	1991 De Beers	115?	2	K1 - K3 pipes (7.9 ha)	4.5	Being evaluated Blue Rock	8.0 Mt, 0.4 Mct
Leicester[5] (RSA)	1892		1	Pipe 6 ha	<9	Together referred to as Elandslaagte Mine	13.7 Mt; 1.25 Mct
Balmoral[5] (RSA)			1	Pipe 1.2 ha			
Russell[5] (RSA)			1	Pipe 2.5 ha			
K14 (Guinea)	1964		1	Pipe 3 ha	8-169	Evaluated by Rio Tinto	
Goedgevonden (RSA)	1910	100- 117	1	1 pipe (2.4 ha)	<5	Uneconomic	
Mitzic (Gabon)	1966, BRGM	2848	1	Dykes, up to 10 m wide	Low	Uneconomic	
Makongonia (Gabon)	2003 Southern Era	2848	1	12 Dykes, 0.3 – 9 m wide, 1 Pipe 1 ha	Low	Uneconomic	

Table 6. Tier-4 deposits (Section 6) Small mines including blows and dykes.

Tier 4 Small mines and dykes							
Mine	Discovered	Age (Ma)	Group	Occurrence	Grade (cpht)	Comments	Production
Otto's Kopje (RSA)	1880	87	1	Pipe 1.2 ha	4.5	Dormant	
St Augustine (RSA)	1884	85	1	Pipe 0.7 ha	64	Dormant	
Kamfersdam (RSA)	1880	87	1	Pipe 4.1 ha	10.5	Dormant	
Makganyene (RSA)	1911	121	2	Pipe 1.1 ha	<3	Dormant	
Peiserton (RSA)	1900	120	2	Pipe 0.6 ha	20 – 30	Dormant	
Postmas 1 (RSA)	1911	119	2	Pipe 0.9 ha	7	Dormant	
Frank Smith (RSA)	Before 1900	113.7	1	2 pipes on older dyke (4.6 ha)	5	Dormant	0.003 (2005)
Kaalvallei (RSA)	1890	85	1	Pipe 1.9 ha	7	Closed in 1993	
Marsfontein (M1) (RSA)	1997 MSA	155.1 ± 0.8	2	Small pipe (0.5 ha)	173	Closed in 2004	1.8 Mct in 2 yrs
The Oaks (RSA)	1988 De Beers	509 - 503	1	2 lobes and neck, 1 ha	34	Closed in 2007	0.98 Mct 0.08 Mct/a
Roberts Victor (RSA)	1905	127 ± 3 - 128 ± 15	2	2 small pipes and blows on dyke	30 – 60	Closed in 1996	0.03 Mct/a
Palmietgat (RSA)	1978 De Beers		1	3 pipes (1.6 ha)	6 - 20	Closed	0.05 Mct (2005)
Blaaubosch (RSA)	1905	133 ± 27	2		18 – 35	Closed in 1967	0.004 Mct (2005)
Total							0.59 Mct/a

° Petra Diamonds Resources and Reserves, June 2013. [4]Blue Rock Diamonds August 2013. [2]Investors Presentation Stellar Diamonds, Q4 2014. [5]VSA Geoconsultants, 2006.

ranging between 2,735 m and 2,460 m. It strikes approximately 100°, which is parallel to the trend of the majority of kimberlites in the vicinity. It comprises hard, macrocrystic coherent kimberlite and averages 1.24 m in width, with a maximum recorded width in outcrop of 2.7 m. It is anomalous in that it has the highest reported grade of any kimberlite in Lesotho (68 cpht at +1.18 mm cut-off). Local artisanal miners have excavated the weathered surface outcrop to a depth of approximately one metre over most of the length of the dyke. The mineral resource of 1.6 Mt is based on four small bulk samples (983 t) taken from surface in 2012 (www.paragondiamonds.com; Lynn *et al*., 2014a).

Gabon

Diamond bearing meta-kimberlites of Archaean age have been found in two areas of Gabon, both on the Ntem Craton.

In northeast Gabon, the Bureau de Recherches Géologiques et Minières (BRGM), discovered a number of ultramafic dykes around Mitzic in the 1960s. These were classified as meta-kimberlite by Bardet (1973), based on the presence of kimberlitic Cr-Spinel and diamonds, along with the whole-rock geochemistry. Petrographically, the Mitzic meta-kimberlites have olivine macrocrysts and are highly micaceous hypabyssal rocks that show variable metamorphic grades reaching amphibolite-facies.

Field work by De Beers in the 1990s showed that these are hypabyssal dykes arranged in an *en echelon* system (Henning *et al*., 2003). The dykes can be followed over several tens of kilometers. They display a large variation in thickness and can be over 10 m wide in places (Henning *et al*., 2003).

Dating of mantle derived zircons yielded a weighted mean average of 2848 Ma which would make these the oldest kimberlites known in the world (Henning *et al*., 2003).

In southern Gabon, the Makongonio area is known for its historical gem quality alluvial diamonds that are still mined today by artisanals. Exploration conducted by SouthernEra Resources, between 2003 and 2006 found one pipe and 12 meta-kimberlite dykes (Bhebhe, 2006). As in northern Gabon only kimberlitic spinels were recovered from samples and this led to the discovery.

The meta-kimberlites are believed to be Archaean in age, mainly due to the similar style of metamorphism, alteration and petrography (Fig. 20) to the Mitzic kimberlites but also because some of the Makongonio dykes are covered by Pan African and Proterozoic sediments (Bhebhe, 2006). Both the Mitzic and the Makongonio

Figure 20. Altered macrocrystic olivines in highly altered clay matrix of one of the Makongonio meta-kimberlites (photo Bhebhe).

meta-kimberlites are diamondiferous but presently not economic and occur in structural corridors. Mitzic meta-kimberlites have a northwest trend (Henning *et al*., 2003) whilst the Makongonio meta-kimberlites have a generally north-south strike direction (Bhebhe, 2006).

West Africa

West Africa has a rich history of diamond production, though primarily from alluvial sources, with discoveries first in Ghana (1919), Ivory Coast (1929), Liberia and Sierra Leone (1930) then Guinea (1933). Official figures are hard to establish, however it is estimated that over 214 Mct, valued at over 21 US$b (based on year 2000 US$), has been produced between the discoveries in the 1930s and 2005 (Janse, 2007).

Sierra Leone, Guinea and Liberia are all underlain by the Archaean part of the Man Shield, which comprises of the Leonian (~3,000 Ma) and the Liberian (~2,700 Ma) geological provinces. Diamond fields in Liberia, Sierra Leone, Guinea, Mali and Ivory Coast are exclusively in the granite and granodioritic gneiss terrain of the Liberian Terrane (Fig. 21).

There are two known age provenances of kimberlites in the Man Craton. The larger Jurassic age provenance comprises six main clusters of kimberlites ranging from the older Bounoudou kimberlites in Guinea at 153 Ma, through to the younger Tongo kimberlites in Sierra Leone dated at 140 Ma. A single neo-Proterozoic cluster is known in the Weasua area in Liberia and is dated at 800 Ma (Skinner *et al*., 2004).

Hypabyssal and transitional facies lithologies tend to dominate with remnants of diatreme facies present in some pipes (e.g. Banankoro, Koidu and Weasua). This suggests potential erosion of up to 2 km over the Man Craton (Skinner *et al*., 2004). However, Sutherland (2007) suggests erosion of the Bounoudou cluster, which hosts the Droujba pipe, is only in the order of 500 m.

The total production figures for Guinea (from 1934), Sierra Leone (from 1931) and Liberia (from 1959) up to and including 2013 are, 19.3 Mct, 65.3 Mct and 15.6 Mct respectively. Production figures from 2008 to 2013 for Guinea, Liberia and Sierra Leone were obtained from the Kimberley Process (2013) and are presented in Table 7.

Pre-2008 production was mainly from alluvial sources (artisanal and semi-mechanised). It is important to note that production increased significantly in 2012 as a result of the Koidu kimberlite mine coming on stream and that production from alluvial sources will be reduced due to depletion.

Production in Liberia of around 0.4 Mct/a, has been exclusively from alluvial sources and primarily from the west of the country. The significant increase in the US$/ct value from 2009 is believed to have been due to smuggling of high value stones into Liberia in response to the introduction of a high royalty on diamonds in Sierra Leone.

The value of the Guinea production has traditionally been the lowest of these countries. However in 2007/8 the increase in production volumes and lowering of US$/ct value is suspected to have been due to Marange goods from Zimbabwe, being smuggled into Conakry. Annual production levels, all from alluvial sources, resumed normality from 2010 at around 0.3 Mct/a and valued at some 40 US$m.

Sierra Leone

There are two main kimberlite clusters and alluvial mining areas in Sierra Leone, at Koidu/Kono and Tongo. Alluvial diamonds are known in many other areas of Sierra Leone, notably along the Bafi and Sewa Rivers where some potholes have yielded extremely high grades of over 1,000 ct/t (Marshall *et al*., 2013). Other rivers such as the Woa, Moa and Mano also have been targeted for alluvial mining, though these are less prolific producers.

Tongo Dykes

Diamond production from the Tongo area has been exclusively from alluvial sources where high grades and high quality stones are renowned, though in general the stone size at Tongo is smaller than that of Kono with no reported occurrence of + 100 ct stones. Both Octéa Mining (Koidu Holdings S.A.) and Stellar Diamonds, are actively establishing resources on the 140 Ma old Tongo dyke swarm where grades of up to 300 cpht are known. Stellar has reported a 1.45 Mct resource over Dyke 1 at a +1 mm grade of 165 cpht and diamond value of between 145 and 270 US$/ct which is now the subject of a feasibility study (Stellar Press release, November 2014). Octéa has yet to announce a resource.

Liberia

Diamonds were first discovered in the Mano River basin (both Sierra Leone and Liberia) in the 1920s, but it was not until the early 1950s that diamonds were mined in western Liberia. All diamond production to date in Liberia has been from alluvial sources with diamond exports fluctuating between 0.3 and 0.8 Mct/a between 1965 and 1983.

There are four districts where diamonds have been found, but it is only in the west and northwest of the country where kimberlites such as Mano Godua, Weasua and Kumgbo/Camp Alpha (Fig. 21)

Table 7. Recent production figures for Guinea, Sierra Leone and Liberia (Kimberley Process, 2013).

	Guinea			Sierra Leone			Liberia		
Year	Ct	US$m	US$/Ct	Ct	US$m	US$/Ct	Ct	US$m	US$/Ct
2008	3,698k	53.7	17.3	331k	98.7	266	47.6k	9.9	210
2009	697k	28.9	41.5	400k	78.4	196	28.3k	11.2	396
2010	374k	27.9	74.7	438k	106.1	242	26.5k	15.9	600
2011	308k	33.4	110.0	357k	124.1	347	41.9k	16.1	385
2012	266k	43.5	163.2	541k	163.2	301	42.0k	16.2	385
2013	203k	33.7	166.6	609k	184.5	303	53.7k	19.7	367

*For Guinea: Chirico et al., 2012.

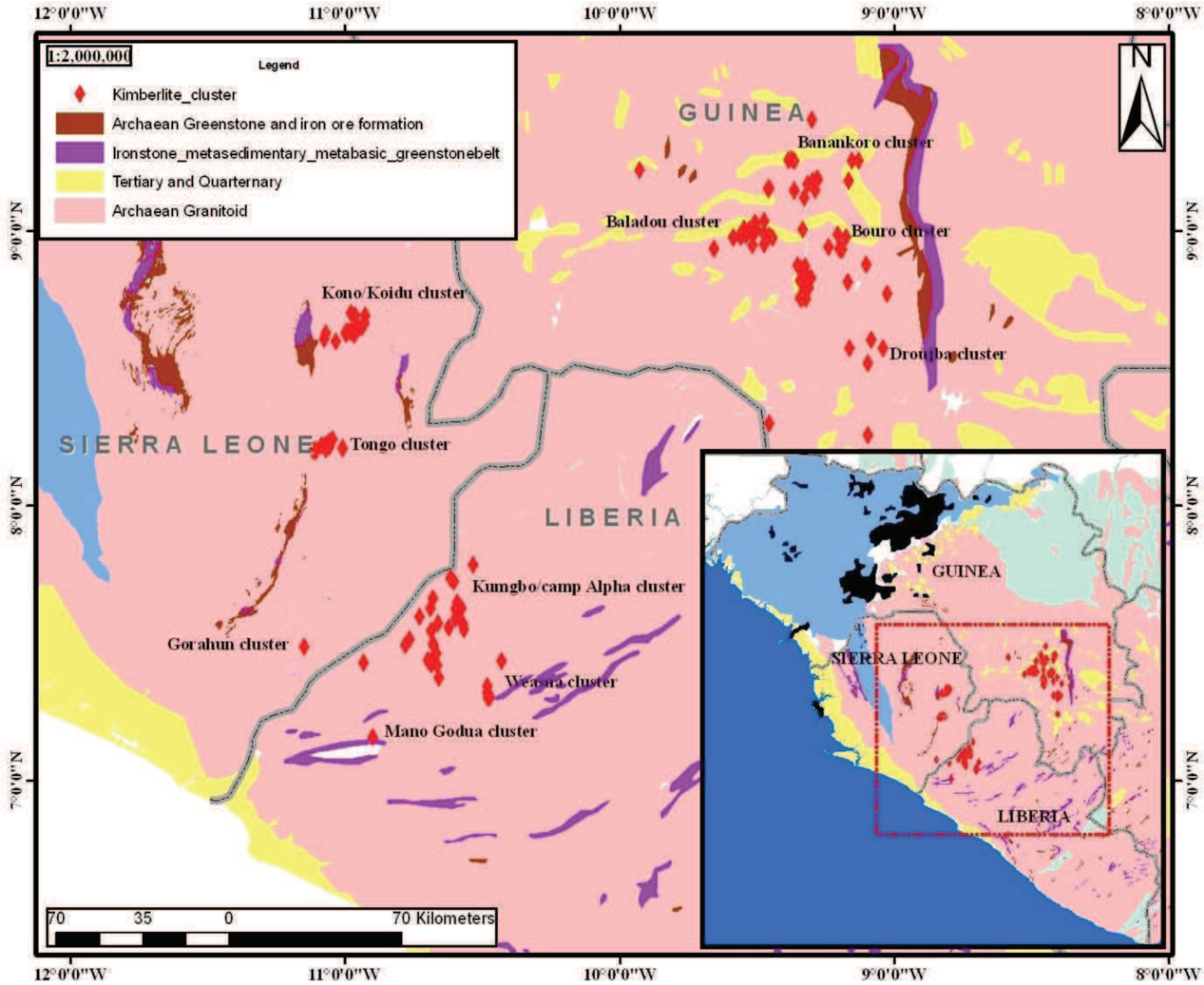

Figure 21. Main diamond districts on the Man Craton covering Guinea, Sierra Leone and Liberia (Courtesy Stellar Diamonds).

have been reported (Haggerty, 1982 and 2014). The Mano Godua occurrence is a small, barren 1 ha pipe. The Weasua cluster comprises five low grade pipes, the largest of which is 4 ha in size.

The Kumgbo/Camp Alpha kimberlites are north-northeast to northeast trending dykes of up to 10 m in width and over 1 km in length with a few having enlargements or blows, some of which are diamondiferous (Stellar Diamonds, 2014). Haggerty (2014 and 2015) recently reported the discovery of a new, elongated pipe (500 x 45 m) in the area to the north of Camp Alpha.

In Nimba County (NE Liberia), diamonds occur in graphitic schists that appear to be part of the Precambrian granite-greenstone basement (2.3 to 2.9 Ma) (Marshall *et al*., 2013), whereas alluvial diamonds in Sino County (SE Liberia) and Magibi County (South-Central Liberia), have unknown sources.

Dykes of the Border and Mano Godua-Kumgbo Trends are Mesozoic (80-135 Ma) in age and classified as Group 1. An older (800 Ma) kimberlite cluster was discovered by Stellar Diamonds in the Weasua area. These pipes are up to 4 ha in size, are diamondiferous and although grades were confirmed at less than 10 cpht, the diamond quality is high and likely to be valued at over 150 US$/ct (Haggerty, 2014).

The dykes and associated blows are texturally hypabyssal but large pockets of fragmental kimberlite are relatively common. The Proterozoic pipes, also of the Group 1 variety, are classified as hypabyssal and diatreme facies kimberlites, with some samples being tuffisitic (volcaniclastic kimberlite).

The alluvial deposits are similar to those in other parts of West and Central Africa and occur in the current river beds and in adjacent river flats as well as low and high-level terraces (Fig. 23). Large stones, in the range of 100 - 200 ct are common in diggings in west Liberia whilst at Camp Alpha, in the northwest, diamonds exceeding 300 ct have been found in alluvial gravels and are presumably of local origin (Haggerty, pers. comm., 2014).

Guinea

There are four known kimberlite clusters in Guinea, all located in the southeast of the country and all associated with alluvial fields. The most prolific of these is the Banankoro cluster where over 20 pipes and dykes were the first to be found in the 1950s. This same area has also produced the most diamonds, including some large stones, from alluvial mining. Other known kimberlites moving south from Banankoro, are the Baladou/Faladou, Bouro and Droujba clusters. Guinea's resource potential was estimated to be 40 Mct with a production capacity of between 0.48 and 0.72 Mct/a (Chirico *et al*., 2012).

Banankoro kimberlites

Kimberlites in the Banankoro area are typically small, with the largest known being 9 ha in size. Grades of the pipes tend to be low (< 20 cpht) with the exception of the K14 pipe (Table 6), where one kimberlite facies within the pipe has a recorded grade of 169 cpht. The area, however, has seen extensive alluvial mining since the 1930s, with the most recent commercial mining by Trivalence in the 1990s to mid-2000s at what was known as the Aredor mine, where a resource of almost 1 Mct at a grade of 5 to 9 cpht was established in 2003 and diamond values of 375 US$/ct were reported (Street wire 08 Dec 2005).

Baladou/Faladou kimberlites

The Baladou/Faladou cluster consists of a series of east-west trending dykes and small pipes up to 3 ha in size. Some kimberlites exhibit very high microdiamond counts (Stellar Diamonds, 2014).

Bouro dykes

The Bouro cluster comprises four east-west trending dykes. Bulk sampling yielded an in-situ grade of over 240 cpht for the Bouro North dyke, though diamond quality was poor at less than 30 US$/ct (Stellar Diamonds, 2012). Stellar also undertook alluvial mining in the immediate vicinity of Bouro on the Mandala project, which yielded over 0.13 Mct at grades of up to 45 cpht (Stellar Diamonds, 2011). Again diamond quality was relatively poor at 30 to 40 US$/ct but the largest stone recovered was a 37 ct fancy yellow stone valued at 0.15 US$m (Karl Smithson, pers. comm., 2015).

Droujba cluster

The Droujba kimberlite cluster comprises a small pipe of 1 ha and 12 dykes (Sutherland, 2007) in the Bounoudou area (Fig. 21). Stellar Diamonds recently established an inferred resource of 2.5 Mct at a grade of 63 cpht and value of 45 US$/ct, over the Droujba pipe to a depth of 300 m (Chisonga and Ferreira, 2012). This average grade includes a country rock breccia on the kimberlite contact. The hypabyssal kimberlite itself has a resource grade of 70 cpht. The 5 km long Katcha Dyke, which cross-cuts the Droujba pipe, has also been tested and an inferred resource of just under 0.5 Mct at a grade of 140 cpht and value of 60 US$/ct was established over a 470 m long strike length, to a depth of 150 m (Chisonga and Ferreira, 2012).

Alluvial mining has occurred in the Bounoudou region since the 1940s and for many years it was the largest diamond producing area of Guinea. Extremely high grades of up to 260 cpht have been recorded near Droujba, but grades of only 25 cpht are currently the norm. In 1988 Hymex established a resource of 1.5 Mct for the Diani River channel and flats, at a value of 30 US$/ct and a resource of 0.35 Mct at an average value of 100 US$/ct for the Avili tributary.

Mauritania (Reguibat Shield)

Diamonds and indicator minerals are found in a large area of the Reggan district of the Algerian Sahara. Within the Bled-el-Mas valley there are late Pleistocene alluvial sediments that contain diamonds (Kaminsky *et al*., 1992). Both octahedral and dodecahedral diamonds have been recovered and the local diamond source is likely to be Early Cretaceous conglomerates. The primary source of these stones is still unknown but a likely source area is to the west in the Eglab shield of the West African Craton. Kimberlites might be Jurassic in age much like the 21 kimberlites found in northern Mauritania (Rombouts, 2003) in the Tenoumer and Touajil areas. These are all Group 1 kimberlites, some of which are weakly diamondiferous and mostly small bodies and dykes (Kaminsky, 2014).

Small diamonds have also been recovered from the base of the Taoudeni basin in Mauritania, believed to be Cambrian in age, but these are too small and sporadic to present an economic deposit.

Main secondary fields in Africa

Diamonds from the Witwatersrand

Diamonds were first found within conglomerates of the Witwatersrand gold mines around Johannesburg in the 1890s and were subsequently recovered from several localities across the Witwatersrand. The largest reported diamond recovered was a 10 ct green diamond near Klerksdorp, and for some mines several hundred diamonds were reported such as 194 ct from the Modderfontein B Gold Mine (Lawn, 1924). In the early days of mining, when less intense crushing procedures were employed, these recoveries were relatively common. One observation of these stones was that they have a green colouration ranging from a nuance of green to bottle green and almost black. This colour was found to be the result of natural radiation coming from the associated uranium minerals in the conglomerate (Raal, 1969).

Although the diamonds recovered from these 2.7 Ga conglomerates are not economic due to their low concentration, they are important in that they are a further indication that kimberlites or related rocks were present during the Archaean.

Orange/Vaal River basin (South Africa)

The Orange/Vaal River drainage basin, the principal drainage of southern Africa, has a total catchment area of almost 900,000 km² (Bremner *et al*., 1990). For the purpose of this summary, the basin has been sub-divided into the Vaal basin above its confluence with the Orange, the Middle Orange between Hopetown and the Augrabies Falls and the Lower Orange from the Falls to the sea (Fig. 24).

Much of this Vaal-Orange catchment (36%) is underlain by the Kaapvaal Craton, and diamondiferous kimberlites in the long-lived erosion of the southern African hinterland have been the source of the interior alluvial diamond fields which have yielded approximately 20 Mct since about 1870 (modified from de Wit, 1996). Walker and Gurney (1985) estimated that at least 3 Bct were liberated in post-Gondwana times and transported to the West Coast of southern Africa. Recently this level of erosion has been challenged and reduced (Hanson *et al*., 2009). The main period of erosion is believed to have been in the early and mid-late Cretaceous (Tinker *et al*., 2008), but gaining some momentum again from about 40 Ma ago and with a peak around 25-30 Ma (Aizawa *et al*., 2000), with subsequent pulses of uplift (incision) and terrace preservation around 15-20 Ma and 3 - 5 Ma as regional, sub-continental aridity set in from west to east (Partridge and Maud, 1987; de Wit, 1996; Jacob, 2005).

The inland alluvials account for only 0.6% of the diamonds that

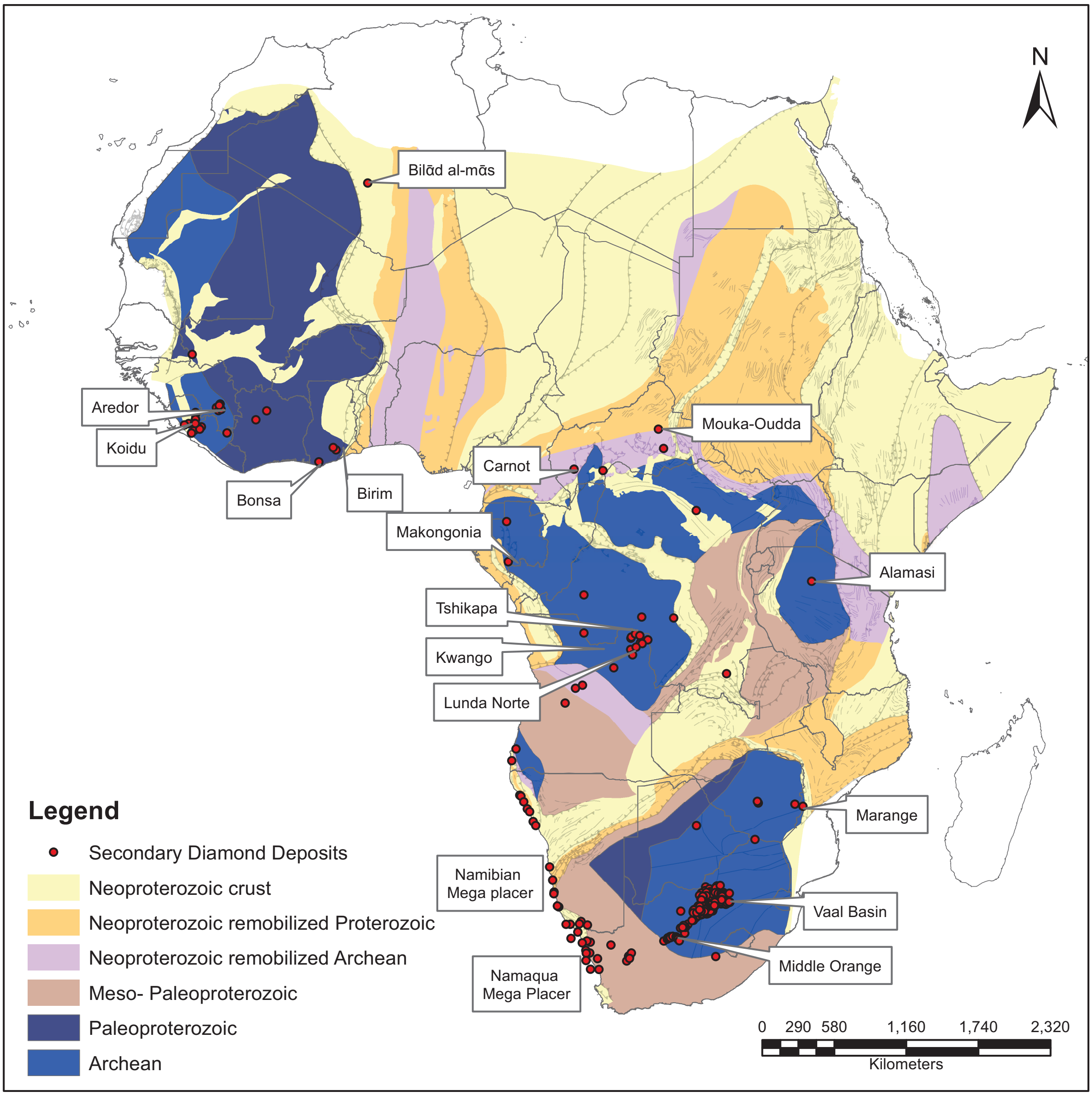

Figure 22. Geological map of the Precambrian basement of Africa (de Wit and Linol, 2015) with known Group 1 (red) and Group 2 (blue) kimberlites, and lamproites (purple), highlighting the main alluvial diamond deposits.

are estimated to have been removed by erosion of the known kimberlite pipes on the Kaapvaal Craton.

The North West Province has produced the bulk of these inland alluvial diamonds. Between 1904 and 1984 the production was: Lichtenburg 10 Mct; Ventersdorp/Potchefstroom/Klerksdorp 3 Mct and Schweizer Reneke/Wolmaransstad/Bloemhof 4 Mct (Marshall, 1990; de Wit, 1996).

The Kimberley area alluvials have produced between 1.5 and 2.2 Mct. Deposits that have produced more than 0.1 Mct include Droogeveldt, the Holpan/Klipdam palaeochannel near Windsorton and Waldeck's gravel splay at Barkley West (de Wit, 1996).

Lichtenburg/Ventersdorp secondary field (South Africa)

The Lichtenburg diamond fields, 200 km west of Johannesburg, were discovered in 1926 and production peaked at just over 2 Mct in 1927. In that year it accounted for almost 75% of South Africa's production and this led to a major threat to the diamond market at the time. From 1926 to 1984 the area produced more than 9.7 Mct and probably over 11 Mct to date. Diamonds are still mined today, albeit on a small scale as most of the gravels have been depleted.

The diamonds occur in gravel runs, potholes and sheets or patches (du Toit, 1951). The gravel runs are sinuous gravel accumulations, which form positive features in the topography. Subsequent reworking of these earlier deposits has produced lower lying and younger gravel which can be found as gravel sheets or patches of gravel, sometimes less than 1 m thick. However it was the high-level gravel that was most productive.

Similar deposits are found around Ventersdorp some 80 km to the east and these have recently been worked on a large scale such as at the Tirisano Mine where Rockwell Diamonds declared a resource of 72.7 Mt and 0.96 Mct at a grade of 1.32 cpht in 2012 (Marshall, 2012).

Table 8. Main secondary deposits in Africa.

Alluvial deposits							
Deposit	Discovered	Past production Mct	Resource			Value US$/ct	Estimated Production Mct/a
			Mt	cpht	MCt		
Southern Africa							
Lichtenburg	1927	9.7					0.002 Small operators
Ventersdorp	1912	2.7				800 -1,000 (2012)	0.001
Tirisano[d]		0.04	72.7	1.32	0.96	726 (2012)	0.05 (Density of 1.8)
NW Province Namakwa Diamonds Ltd.[e]	1912	4.0	268	0.39	1.1	765 (2012)	0.05
Lower Vaal River	1868	1.5	1.54	0.2	0.31		0.025
Holpan/Klipdam[b]	1870s	0.13	22.3	0.46	0.10	751 (2012)	0.001 2mm cutoff
Middle Orange River (MOR)	1926					1,900 (2013)	0.005
Rockwell (MOR)[c]			156.6	0.33	0.53		0.008
Namaqualand*		53.0[g]	90.1	6.1	5.5	112 - 260[H]	
Lower Orange (DB)*	1960s	3.8[f]	154.7	0.5	0.7	805[I]	0.08
Namibian onshore*	1908	78.4	372.3	1.9	6.9		0.35 (2011)
Namibian offshore*	1972	20.2	1.155 Mkm²	0.1 cpm²	90.7		0.99 (2011)
Marange (Zim)	2001	100				30	3
Chimanimani (Zim)	2001	0.02					0.01
Kwango (Ang)	1921					500	0.25 - 0.7
Lunda Norte (Ang)	1912	116				250-400	0.2 - 0.5
Central Africa							
Northern DRC	1915					200	0.5 - 1
Tshikapa (DRC)	1907	84				80-120 (2011)	2 - 3
Sankuru (DRC)	1918					20	3 - 5
CAR Carnot	1913	24.2			26.5	200	0.45
CAR Mouka-Oudda						200	
Alamasi (Tan)	1940?	0.5					0.001
West Africa							
Ghana Birim	1919	94.5				12	0.16
Ghana Bonsa	1922	10.5				12	0.01
Guinea Total	1933	19.3	40				0.5
Aredor[a]				4 -10	0.943	350	
Liberia Total	1930	15.6					0.05
Sierra Leone	1931	39				500	0.03
Total		**677.07**					**15.97**

*Anglo American Ore Reserves and Mineral Resources report 2013. [c]Rockwell Resources RSA (Pty) Ltd Technical statement 2010, 2012 (SG 2.1 used for conversion). [a]SRK, 2003. [b]Rockwell Resources Inc. (Marshall), 2012. [d]Rockwell Resources Inc. (Marshall), 2012. [e]Namakwa Diamonds Ltd Annual report 2012. [f]Past production includes De Beers (1.3 Mct), Transhex THG (1.8 Mct), Octha (0.8 Mct) Barker Mining and Metal (0.03 Mct). [g]Past production includes De Beers, Transhex on and offshore and Alexkor. LOR = Lower Orange River, MOR = Middle Orange River. [H]Transhex, 2013. [I]Average value for total Namibian production in 2013 (Janse, 2014).

Schweizer-Reneke/Wolmaransstad/Bloemhof alluvial field (South Africa)

The Schweizer-Reneke/Wolmaransstad/Bloemhof alluvial diamond fields, also in the North West Province, have been economically exploited by local diggers since the turn of the previous century and close to 4 Mct of diamonds have been recovered from these gravel deposits (Marshall, 1990).

Four different ages of alluvial gravels (A0 to A3) and a derived (colluvial and eluvial) gravel have been recognised (Fig. 23). The colluvial gravels usually occur on interfluves overlying the oldest alluvial (A0) deposits. The younger (A1-A3) deposits are developed both outside of, and within, the present day valleys. The stratigraphy of these deposits has been described in detail (de Wit *et al*., 2000) and they are time-equivalent tributary deposits of the Vaal River terrace gravels developed lower downstream (Helgren, 1979; Partridge and Brink, 1967).

The Rooikoppie ("*Red Gravels on a Hill*") deposits represent a derived remnant of the oldest river terraces (Marshall, 2004). They are enriched due to the decomposition and winnowing of the less resistant material which substantially concentrated the more durable components such as diamonds. These deposits occur over large areas but exhibit low volumes, since they are typically less than 1 m thick.

The known grades of the fluvial-alluvial gravels range from 0.1 to over 2 cpht in favourable trapsites but average around 0.5 cpht. This ca. 90% gem population is dominantly commercial white in colour, with rare pink, blue and vivid orange fancy stones occuring along with Type IIa diamonds up to 26 ct. The average stone size range is 0.7 - 1.5 ct/stn, with >100 ct diamonds being exceedingly rare. A significant proportion of the diamonds display signs of light to heavy physical abrasion, including unusual but distinctive scratch-like markings. Average (2014) diamond values are in the range of 800 to 1000 US$/ct, but values over 2,000 US$/ct are known for exceptional stones.

Lower Vaal River

The first diamond diggings in the lower Vaal River started in 1870 in the Barkly West area (de Wit, 2008) near Kimberley. Since then activities have centred around Windsorton, Barkley West and Douglas. The Orange-Vaal placers are found mainly as gravel splays deposited in pre-Karoo topographic depressions at the exit points from bedrock channels incised into Pre-Karoo, mostly Archaean, Ventersdorp rock types. These pre-Karoo depressions can be of a local scale, < 1 km long, or on a sub-basin scale up to 75 km long, as is the case in the Middle Orange placers downstream of the Orange-Vaal confluence. Production figures are not always accurate, especially from the early operations but the following are the best estimates: Holpan/Klipdam (Windsorton) 0.15 Mct (Cooke, pers. comm.); Droogeveldt (Barkley West) 0.49 Mct; Nooitgedacht (Barkley West) 0.076 Mct and the Waldeck's gravel splay (Barkley West) 0.53 Mct (de Wit, 1996). This represents a total production of well over 1 Mct. In this reach of the lower Vaal River and over one hundred +100 ct diamonds have been recovered, the largest being the 511 ct Venter diamond from the farm Nooitgedacht (de Wit, 2004). Although sporadic mining operations are ongoing, these are on much depleted ground with low grades.

Middle Orange River

Several junior companies are successfully exploiting some of the terraces along the Middle Orange River between Hopetown and Prieska. Palaeochannel remnants are preserved at different elevations above the present river: Lower C Terrace 0 - 30 m, Intermediate B Terrace 30 - 60 m, Upper A terrace 60-90 m and high terrace of +110 m (Gresse, 2003). In addition, thin diamond-bearing Rooikoppie gravels blanket some of the higher areas and these have also been exploited. The age distribution varies from Miocene, for the higher terraces, to Pleistocene for the lower terraces. Rockwell Diamonds Inc., one of the major operators along the Middle Orange, treated some 9.58 Mt between 2009 and 2013 and produced 0.03 Mct at an average grade of 0.3 cpht. At a lower cut-off of 2 mm, their average stone size was 3.3 ct/st with an average value of 1,900 US$/ct. In 2013 Rockwell recovered a 287 ct diamond and at regular intervals they recover + 100 ct stones. Other operators along the middle Orange include Steyn Diamonds and Manhattan Corporation, all operating on low-grade deposits that have occasional large and high-value diamonds, commonly Type IIa D stones of exceptional quality, recovered. These white-coloured gems have probably been derived from the Cretaceous age Jagersfontein and Koffiefontein kimberlites in the Riet River catchment, and Lesotho kimberlites in the uppermost

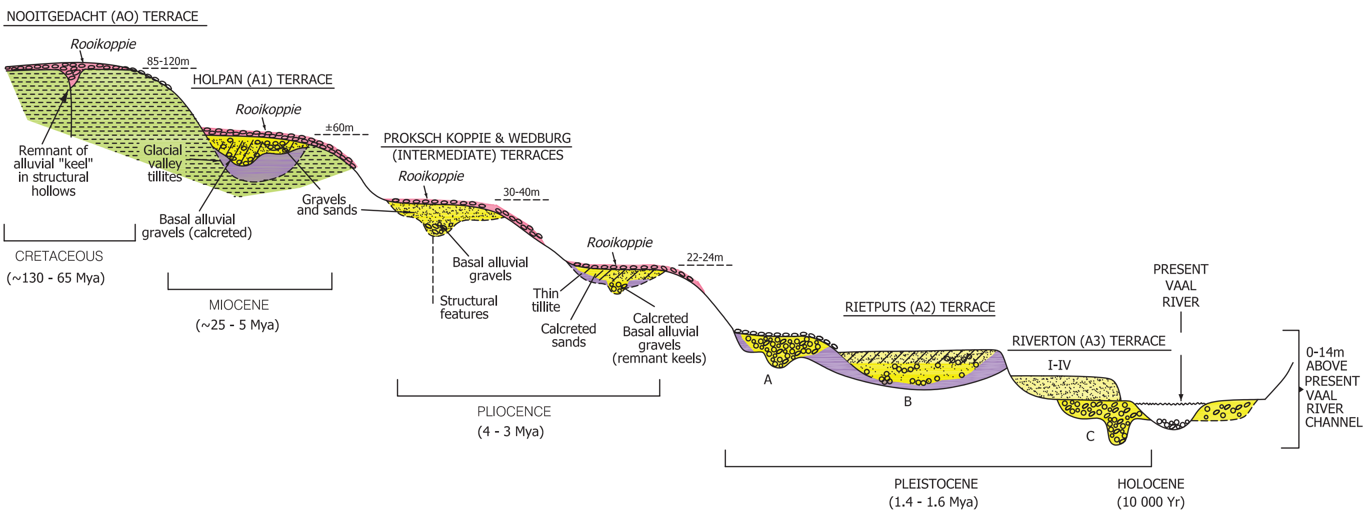

Figure 23. Schematic section through the gravel terraces of the Vaal River (Marshall, 2004).

Orange River catchment. Production from the Middle Orange River is less than 0.5 Mct in total.

Lower Orange River terraces

A palaeo-delta, dominated by sand and mud, lay offshore of the present Orange River mouth and existed from c. 103 Ma to between 60 and 70 Ma (Brown *et al*., 1995; Aizawa *et al*., 2000). It was fed by an older, mature drainage network which had been superimposed onto the landscape (du Toit, 1910; van Wyk and Pienaar, 1986; Partridge, 1998; de Wit *et al*., 2000). This Late Cretaceous system was incised following the Late Cretaceous epeirogenic uplift that is clearly recorded in the offshore Orange Basin (Brown *et al*., 1995). The Orange/Vaal system therefore evolved from a free-meandering, large drainage system with a fine grained (sand/silt) discharge in the Late Cretaceous - Early Tertiary to a superimposed, steeper, bedrock-confined, gravel transporting channel system since the Early Tertiary (Bluck *et al*., 2005 and 2007).

Although a major conduit for diamonds to the Namibian megaplacer, it was only in the 1960s that economic quantities of diamonds were proven in the actual Orange River deposits themselves (Wilson, 1972). The diamondiferous deposits of the Lower Orange have produced approximately 3.8 Mct to date at an average size of over 1 ct/st (Table 9), which includes production from Namdeb, Transhex, Octa (Namex) and Barker's Metal and Mining (Jurgen Jacob, pers. comm., 2014). The average dollar per carat value for the whole of Namibia in 2013 was 805 US\$/ct (Janse, 2014) but Tango Mining achieved 1,790 US\$/ct in 2007 from their Oena river deposit in the lower Orange (www.tangomining.com).

Two principal suites of river terraces developed along the Lower Orange River after most of the incision had occurred: an older, higher lying *Proto* suite and a younger *Meso* suite (Fowler, 1976; Jacob *et al*., 1999; Jacob, 2005). The *Proto* suite represents a long, post-Eocene to Early Miocene, phase of incision, followed by a prolonged period of aggradation where up to 90 m of fluvial, diamondiferous deposits accumulated during the Early to Middle Miocene (Jacob, 2005). The basal part, the Arries Drift Gravel Formation, is well dated to between 17.5-19 Ma (Pickford and Senut, 2002). The *Meso* suite of deposits represents shorter phases of incision and aggradation in the Plio-Pleistocene (Jacob, 2005). The *Proto* suite is more significant economically, due to it hosting the highest grades in degradational deposits developed over longer periods of time. The *Meso* deposits have only proved to be economic in localised areas (Van Wyk and Pienaar, 1986; Jacob *et al*., 1999; Jacob, 2005).

Coastal deposits of Namibia and South Africa

The Lower Orange River has been the primary conduit to the most spectacular regional secondary gem diamond occurrence yet discovered - an area stretching over 1500 km from the Namaqualand coast of South Africa northwards to the Skeleton Coast of Namibia (Fig. 24) (Hallam, 1964; Corbett, 1996; de Wit, 1996; Bluck *et al*., 2005). Since the initial discovery near Lüderitz in 1908, this region has produced at least 156 Mct of gem quality diamonds - the bulk of which were derived from the Namibian deposits along the Sperrgebiet coast. In this regional province, the diamonds are hosted in a variety of placer types that include fluvial, marine, deflation and aeolian settings, with temporal ranges from at least the Cretaceous to the modern day. Two distinct, separate coastal deposits, defined as 'Megaplacers' by Bluck *et al*. (2005) exist: namely the Namaqualand and Namibian megaplacers (Fig. 24).

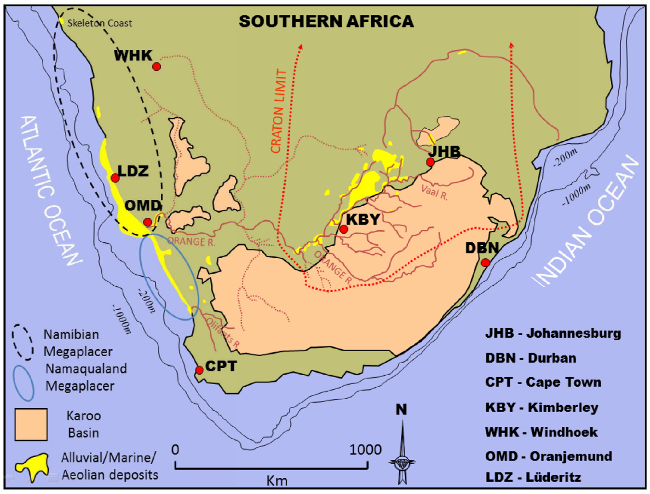

Figure 24. Locality map of the Orange River system and the Namibian and Namaqualand megaplacers.

The Namaqualand Megaplacer

Although the Orange River has been identified as the point source of diamonds to the Namibian megaplacer, the Namaqualand megaplacer, stretching from the Olifants River in the south to the Orange River, has a number of potential input points and sources of diamonds. These include a Cretaceous aged palaeo-Orange or 'Karoo' River, which entered the ocean near the site of the current Olifants-Sout drainages (Dingle and Hendey, 1984; de Wit, 1999), and a Dwyka Group glacial source of diamonds (Maree, 1987; Moore and Moore, 2004), aided by numerous short-reach rivers draining to the west of the escarpment. Bluck *et al*. (2005) support the Karoo River or some form of craton-derived river system, existing from 117.5-103 Ma. Recent dating of diamonds from both megaplacers (Phillips and Harris, 2009) indicates that a Dwyka source of the diamonds is improbable.

Initially discovered in 1925 (Carstens, 1962), the Namaqualand mega-placer deposit consists of a compound of beaches, small fluvial channels and weathered gravel of uncertain origin. The fluvial paleochannels were dated using pollen to the Paleogene and Neogene (Pether *et al*., 2000). Some of these channel systems have been reworked by marine processes during transgressive and regressive cycles and have some of the highest concentrations of diamonds (Rogers *et al*., 1990). Neogene deposits include the 90 m, (heights above present sea level), the 50 m and the 30 m packages. These have been transgressed by younger, littoral deposits of the 8-12 m, the 4-6 m and the 2-3 m packages (Rogers *et al*., 1990). The majority of diamonds were sourced from the Buffels Marine complex (the 50 m package), which extends approximately 40 km northwards from the mouth of the Buffels River. The basal gravel unit forms the main ore horizon in most cases, with preferential concentration in bedrock traps developed on competent quartzite (Rogers *et al*., 1990).

Approximately 53 Mct of diamonds have been recovered from the Namaqualand megaplacer, the bulk coming from the onshore operations (De Beers, Buffelsbank and Transhex) at Koingnaas, Kleinsee and the Buffels River deposits (40.0 Mct), Alexkor operations centred around Alexander Bay (12.0 Mct) and a smaller amount from Namaqualand's offshore concessions 2b, c, 3b, 5a, b, 6a, b, 7a, 11a, 12a and 13a (1.3 Mct). The value of the diamonds in Namaqualand in 2013, excluding Alexkor, ranged from 112 US$/ct at Brand se Baai (average stone size 0.08 ct/st) to 260 US$/ct for the Buffels Inland Complex (0.34 ct/st) (Transhex, 2013).

The Namibian Megaplacer

Diamonds were first discovered near Kolmanskop (east of Lüderitz) in 1908 and worked by a number of German-controlled companies. In 1920 these companies were amalgamated by the late Sir Ernest Oppenheimer to form the Consolidated Diamond Mines of South West Africa. In 1974, this company was incorporated as CDM (Pty) Ltd., a De Beers subsidiary and in 1994 De Beers formed a 50/50 partnership with the Government of the Republic of Namibia, giving rise to the current Namdeb Diamond Corporation (Pty) Limited.

From 1908 to 2014, approximately 102 Mct of gem quality diamonds have been produced (Table 9) including from the Lower Orange River production. Most of the remaining potential is in the marine and shallow water deposits.

Namibian Coastal Deposits

Mining Area No.1 deposits were discovered in 1928 and occur north of the Orange River mouth for some 110 km. These deposits have produced an estimated 62 Mct of diamonds (Table 9) and comprise Pleistocene to Holocene marine placers preserved between about +30 and -20 metres above sea level (masl). The higher lying marine deposits, between about 12 and 30 masl, are earliest Pleistocene in age and the younger ones are found at elevations below 10 masl. The present-day marine deposits north of the Orange River mouth lie unconformably on well-gullied to well-planed Neoproterozoic bedrock and the intertidal and nearshore sub-tidal platform gravels commonly host the best diamond concentrations (Hallam, 1964; Ward *et al*., 2002; Spaggiari *et al*., 2006), especially in bedrock gullies that acted as fixed trapsites.

However, the majority of these world-class marine placer deposits have been mined out. Farther north between Chameis Bay and Lüderitz, deposits are confined to smaller pocket beach deposits, as well as deflation and aeolian placers. In the coastal central Sperrgebiet some 140 -180 km north of Oranjemund, marine deposits in the Langental area have been dated to the Middle Eocene, c.42 Ma (Stocken, 1978; Corbett, 1989). These marine deposits have a characteristic Vaal-Orange clast assemblage signature with agates, yellow chalcedonies, green chrysoprase and red jaspers. Most of these placers lie in the deflation basin, where salt weathering and aeolian abrasion ensure an upgrade in sediments to chemically resistant types resulting in some spectacularly rich grades (Ward *et al*., 2002). Diamond sizes decrease from approximately 1 ct/st near the Orange River mouth, to less than 0.1 ct/st to the north of Lüderitz as the distal parts of the placer are reached.

Table 9. Total diamond carats produced from the different components of the Namibian Megaplacer.

Namibian Mega placer domains	Mct
Lower Orange River	3.84
Mining Area No. 1	62.06
Deflation and aeolian	15.80
Offshore (MDC, Namdeb, ODM, Namco, Sakawe, DFI)	20.18
Saddle Hill & Conception Bay	0.45
Skeleton Coast	0.03
Total	**102.36**

Namibian Offshore Deposits

Offshore mining in this area was pioneered by a Texas oilman, Sammy Collins in the early 1960s (Williams, 1996). However, it was only in the 1970s that the significant deposits, situated in the Atlantic 1 mining licence, offshore and adjacent to Mining Area No.1, in water depths of 120-140 metres below mean sea level (mbmsl) were discovered. The deposits consist mostly of thin accumulations of coarse clastic gravel, overlying an Eocene and Cretaceous clay footwall (Foster, 1996). Following a long period of prospecting and development, mining of these deposits started in earnest in the early 1990s, and approximately 20 Mct have been mined to date from the offshore areas (Table 9). The greatest remaining potential along the west coast is located in these deposits.

Marange (Zimbabwe)

The Mesoproterozoic Umkondo Group is preserved in a shallow basin on the eastern margin of the Zimbabwean Craton (Ward *et al.*, 2013). It is a siliciclastic - carbonate sedimentary succession, overlain and intruded by younger basic volcanics and intrusive dolerites which have been dated to 1,105 Ma (Wingate, 2001). Along the western margin of the basin, the thin basal arkosic gritstones and rare pebble-cobble conglomerates, rest unconformably on well-planed Archaean Basement granites and have been interpreted as a proximal terminal placer on the margin of the Zimbabwean Craton. Repeated and probably long-lived reworking, possibly by tidal processes in this shallow depression, upgraded the diamond concentration which has a large average stone size (Ward *et al*., 2013).

At Marange, the lowermost conglomerate, less than 1 m thick, contains abundant coarse (5-7 ct/st) diamonds and was discovered in 2001 by De Beers. Initial grade estimates ranged from 100 cpht to >3,000 cpht.

Although the average stone size is the largest of any known diamond placer, the overall diamond quality is low (Fig. 25) - running (±10% gem) at an average price of around 30 US$/ct (2013). Octahedral and rounded shapes are dominant and most diamonds display signs of irradiation, with brown spots, reflecting a likely thermal influence. Although some diamonds display abrasion features such as percussion scars, the high degree of rounding may reflect primary growth attributes rather than physical wear.

For at least 35 km into the basin, the laterally-confined basal conglomerate thins to a 0.05 m thick, lower-grade pebbly gritstone dipping to the east, much of it buried by younger Umkondo sediments.

Since 2006, this Mesoproterozoic placer and its secondary Quaternary (Holocene) proximal alluvial derivative placer (from weathering of the ancient placer), yielded in the order of 100 Mct (Zimnisky, 2014). However the resource is rapidly depleting with two of the seven operating companies (Anjin and Marange Resources) having closed.

DRC Kasai West

Exploration for diamonds in the Congo Belge (DRC) started in 1900 with TCL (Tanganyika Concessions Limited) finding the first diamond in the Katanga Province in 1903. Further exploration by the company led to the discovery of a large but uneconomic kimberlite field on the Kundelungu plateau in 1908. The first diamond in the Kasai region was found near Tshikapa in 1907 by Forminière which became part of the alluvial mines around Tshikapa that ultimately produced close to 90 Mct in the DRC alone (Forminière 1956; de Wit and Jelsma, 2015). This is part of the largest diamond megaplacer in central Africa stretching from the Lunda North Province of northern Angola, into Kasai West Province in southern DRC (Fig. 24). In excess of 200 Mct have been produced since its discovery in 1907. To date no kimberlites have been found in the Kasai West Province (DRC).

Diamonds occur in the Cretaceous-age Calonda Group (Angola) and Kwango Series (DRC), which was almost contemporaneous with the emplacement of the Mid Cretaceous Angolan kimberlites. The latter was the first known input of diamonds into Kasai West and subsequent multiple recycling events provided diamonds from Pliocene to Recent alluvial deposits comprising terraces, floodplains (or flats) and modern rivers. The period between the Pleistocene and Recent was probably the most vigorous recycling event.

Some 92% of the diamonds have come from recent river flats, modern rivers and their tributaries, compared to those derived from older river terraces. Historical mining grades were highly variable ranging from 0.5 to 1,050 cpht, with the majority falling between 0.5 and 50 cpht. Higher grades of 110 cpht or more were derived mostly from pot-holed hard rock riverbeds in modern rivers and included exceptional returns of up to 1,050 cpht. Grades of the river terraces were much lower (0.5-70 cpht). Average diamond size was equally variable with 0.05-0.1 ct/st dominating production parcels, with the largest diamonds being in the range of 2-20 cts/st. The largest diamond found was 35 ct, but unsubstantiated accounts have been made of diamonds up to 60 ct by artisanal miners.

The Kasai West alluvial deposits therefore provide high-grade, small-stone targets with an average value of 80-120 US$/ct. More significantly, the mineralisation model of these deposits differs to that of the southern African alluvial diamond fields. Economic potential increases from older (almost barren), through younger (low grade) to modern alluvial courses (high average grades). This trend is attributed primarily to the rapid incision of rivers through a soft cover into competent bedrock during the Plio-Pleistocene. The vigorous recycling of diamonds, their dispersion and concentration is therefore youthful and continues today.

Forminière continued with its regional exploration program and in 1918 discovered diamonds near Bakwanga, when geologist George Young recovered 8,840 diamonds in one stream sample in the Bushimaie River. This became one of the highest concentrations of alluvial/eluvial diamonds in the world and in the early 1950s produced some 75% of world diamonds (Fieremans, 1953; Forminière, 1956). Alluvial diamonds were also discovered in the northern DRC in the provinces of Equateur and Orientale around 1915, but as is the case in the Central African Republic (CAR), no kimberlites have ever been reported there.

Central African Republic (CAR)

Alluvial diamonds are found in two main areas in the CAR. In the west of the country diamond diggings are focussed around the Lobaye, Mambéré and Sangha drainages near Carnot and Berberati, and are associated with the Carnot sandstone. The other, in the east-central region around the upper Kotto drainage, is associated with the Mouka-Oudda sandstone. Both these sandstone units are Cretaceous in age (Censier and Lang, 1999) and initial studies have suggested that their lower units are diamond-bearing. Hence, it is believed that the Mouka-Oudda and Carnot sandstones are secondary host rocks. It has also been suggested that the Palaeozoic glacial sediments underlying the Mouka-Oudda and Carnot sandstones may be diamondiferous. Yet diamonds are not mined from the Cretaceous nor the Palaeozoic sediments but only from recent alluvial terraces and river flats generally overlying the Mouka-Oudda and Carnot sandstones and in valleys eroding these sandstones (Censier, 1996). No kimberlites have ever been reported from the CAR.

Present production is almost entirely driven by artisanal workings and it has been estimated that there are between 60,000 and 100,000 diggers in the CAR (Dietrich, 2003). Production from these operations has been estimated to be some 0.45 Mct/a although this figure could double due to the activities of illegal miners (Chirico *et al*., 2010). Historical production between 1931 and 2012 has been estimated at 24.2 Mct (Kimberley Process, 2012). Chirico *et al*. (2010) believe, based on a detailed resource assessment of these two known diamond areas, that there are some 39 Mct remaining to be exploited. However since grades of less than 0.05 cpht would probably not be worked, only ±26.5 Mct in so-called ‘concentrate’ areas, are believed to be worth extracting (Chirico *et al*., 2010).

Lower valued carbonado diamonds make up some 30% of the western region’s production and 7% of that in the central region (Chirico *et al*., 2010).

Cameroon

Since their discovery in 1948, diamonds in Cameroon have been exploited primarily by artisanal miners and mostly in the southeastern part of the country, particularly along the Mobilong River (Phillipson, 1985). The diamonds are concentrated in a Holocene to Present alluvial floodplain and channel gravels that are confined to small-scale tributaries. The deposits are therefore thin (average gravel thickness of 0.4 m) and have limited areal extent.

The greater Mobilong area is underlain by Proterozoic rocks (UNDP, 1989). These rocks are weakly metamorphosed and display obvious tectonic deformation. Apart from Holocene sediments no other post-Proterozoic formations have been found. Given that the tributaries incise Proterozoic basement, the meta-conglomerates are considered to be diamondiferous and this is now being investigated by C&K Mining. However, it is also possible that the diamonds may be erosional residues of the Cretaceous Carnot Formation that extended from the Central African Republic (CAR) into eastern Cameroon (Censier and Lang, 1999).

The Mobilong alluvial deposits are low grade and produce small diamonds. Two diamond populations, which are strongly reminiscent of the CAR Berberati diamonds, are apparent (Ward, 2013): a gem quality (75-85%) population and a carbonado population.

Gem quality diamonds average 0.2 ct/st in size, with the largest recorded so far at 7.16 ct, although there are unsubstantiated reports by artisanal miners of diamonds of 20 ct having been found (Phillipson, 1985). Colour varies from colourless (with highly transparent varieties), through green (possibly irradiated) to orange-

Figure 25. Contrasting diamonds from two alluvial deposits in Africa. Some low quality diamonds from the Marange deposit (photo Ward) in Zimbabwe (left) and an assortment of diamonds from gravels of the Mobilong area in Cameroon (photo Spaggiari), illustrating the mix of carbonado (large greyish-black particles in image) and 14.63 ct of gem green diamonds (right).

brown assortments (Fig. 25). The carbonado diamonds on the other hand are significantly larger averaging 2.4 ct/stn. They represent about 15% of the diamond production, a percentage that is similar to CAR diamonds (Censier and Tourenq, 1995). Recently, the largest carbonado recovered at Mobilong was 15.12 ct. No primary source(s) have yet been discovered for Cameroon's diamonds, and the diamond distribution along the Cameroon-CAR border and the similarities to the CAR stones may suggest a common source.

The Ghana diamond fields

Diamonds were first found in Ghana in 1919 near the Birim River close to Akwatia. In 1922 another field was found in the Bonsa River further to the southwest and these are referred to as the Birim and Bonsa diamond fields. These are exclusively alluvial deposits and no diamond bearing kimberlites have been found in this part of West Africa. However, diamonds have been recovered from actinolite-tremolite schists that have been interpreted as 'syn-eruptive volcaniclastic mega-turbidites, derived from a diamond-bearing komatiite' much like some of the diamond bearing rocks that have been described in French Guiana in South America (Canales, 2005). Field evidence suggests that these komatiitic rocks are coeval with the metasediments indicating an age of 2085-2155 Ma for the diamond deposit.

The grades of the alluvial deposits are highest for the river flats, and decrease in both the lower and higher terraces having been quoted as being 43 cpht, 24 cpht and 16 cpht for the Birim deposits and 27 cpht, 14 cpht and 7 cpht for the Bonsa deposits respectively (Chirico *et al*., 2010).

The diamonds are generally small with average stone sizes of 0.033 ct/st for Birim and 0.025 ct/st for Bonsa and both fields have a high percentage of industrial diamonds of between 35 % and 45 % (Chirico *et al*., 2010). Most of the diamonds are macles or dodecahedral crystals and abrasion features appear more prominent on those from the Bonsa area.

It is estimated that of the 105 Mct that have been mined in Ghana, 94.5 Mct are from the Birim area and 10.5 Mct from Bonsa. It has also been estimated that there are still 89 Mct and 2.6 Mct left in the Birim and Bonsa fields respectively (Chirico *et al*., 2010). However, due to the patchy nature and lower grades of the remaining deposits most of these would not be economically viable except as a by-product of gold dredging operations in the Bonsa region or as artisanal operations.

Concluding remarks

It is extremely difficult to summarise all the diamond resources in Africa due to poor reporting in some of the more isolated regions where artisanal activities prevail. However, the Tier structure allows for the more important producers to be ring-fenced with more accurate databases, leaving the smaller producing assets with less well-defined resources for upgrading as new information becomes available. This approach highlights the following:

1. The annual production of the Tier-1, Tier-2, Tier-3 and Tier-4 deposits is 32.46 Mct, 9.63 Mct, 2.24 Mct and 0.59 Mct respectively. Diamond production from secondary deposits is more difficult to quantify because a large proportion is of artisanal nature, but is estimated to be around 15.67 Mct.
2. It is also estimated that the Tier-1 deposits contain some 1,239.3 Mct of diamonds which is probably somewhat conservative as the tailings have not been incorporated as resources. The ten Tier-2 deposits have an order of magnitude less at 266 Mct and the 16 Tier-3 deposits hold roughly 89 Mct. The resources of the main alluvial fields in Africa will become depleted fairly soon in many regions such as Marange, Kwango, Aredor etc. and their contribution will decline in the short (Marange) and medium term.
3. The estimated annual alluvial production in Africa is between 15 and 20 Mct, and these have contributed nearly 700 Mct of the total of 3,200 Mct or almost a quarter of the diamonds that have come out of the continent.

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Glossary

Units

Load:	One load is measured as roughly three quarters of a tonne (Churchill, 1892).
Ct:	one carat = 200 milligrams = 0.2 gram
Kct:	Thousand carats
Mct:	Million carats
Bct:	Billion carats
Cpt:	Carats per tonnes (tonne = metric ton)
Cpht:	Carats per hundred tonnes (tonne = metric ton)
ct/st:	carat per stone (stone = one diamond)
US$/ct:	United States dollars per carat
Mct/a:	Million carats per annum
Mt/a:	Million tonnes per annum
t/d:	tonnes per day
ha:	hectare = 10,000 m^2 = 0.01 km^2
masl:	mean average sea level
mbmsl:	metres below mean sea level

Acronyms (kimberlite types as per Scott-Smith et al., 2013)

BVK:	Brecciated volcaniclastic kimberlite
CK:	Coherent kimberlite
MK:	Macrocrystic kimberlite
MVK:	Massive volcaniclastic kimberlite
PK:	Pyroclastic kimberlite
RVK:	Re-sedimented volcaniclastic kimberlite
TKB:	Tuffisitic kimberlitic breccia (historical nomenclature for massive volcaniclastic kimberlite-MVK)
VK:	Volcaniclastic kimberlite

Mike de Wit *has been in diamond exploration for 40 years, almost entirely in Africa, of which 29 years were for the De Beers Group. His interests include the secondary dispersal of diamonds in various distributary systems and using this as a means to find primary deposits, as well as the application of scientific principles in exploration.*

Zi Bhebhe *has over 20 years of experience as a mine and exploration geologist having worked across a number of continents including Africa, North America and Australia. Zi has worked for both junior companies and majors, and is currently based in Brisbane.*

Jim Davidson *initially spent 6 years of his career in all aspects of diamonds, base/precious metals, coal and Uranium. The subsequent 40 years he was focussed on diamonds, where he worked for several majors after which he become involved in the listing of a company with several fissure mines. After a merger of this company with Petra Diamonds he became technical director of Petra.*

Stephen E. Haggerty *is a distinguished Research Professor from Germiston, and globally educated with major interests in universal diamonds, oxide mineralogy and geomagnetism. He is the discoverer of the deepest (>300 km) rocks, and also a former owner of Jagersfontein. Currently he is active in West Africa and India.*

Paul Hundt *is an exploration geologist with 25 years of experience in Africa and North America, initially focussing on diamond exploration, with a decade in Angola for the De Beers Group and BHP Billiton. Currently with Rio Tinto Exploration he is focussed on bulk and base metal commodity projects in Southern Africa.*

Jurgen Jacob *has spent 20 years on the West Coast of southern Africa unravelling various parts of the Namibian megaplacer and works for Namdeb Diamond Corporation (Pty) Limited. During this time, he completed a PhD on the Lower Orange River deposits.*

Mike Lynn *has been involved in diamond exploration and evaluation for over 30 years, both for a major and a service company, working all over Africa and India. He is a co-author of the standard references on diamonds in South Africa, and has a particular interest in low grade, high value diamond deposits such as those recently developed in southern Africa.*

Tania R. Marshall *has been involved in the evaluation, exploration, prospecting, mining and valuation of alluvial diamond deposits since 1985. She has worked for both large and small companies in this field as an operator and also as a consultant.*

Charles Skinner *has been with the De Beers Group for the past 29 years. In late 2006 he was appointed as Head of Exploration for the Group, leading its worldwide search for primary diamond deposits.*

Karl Smithson *is the chief executive of Stellar Diamonds that is developing diamond projects in West Africa. Karl has 27 years of resource sector experience gained with a number of junior companies and the De Beers Group, where he has spent most of his career on diamond exploration and on advanced diamond projects in Africa.*

Johann Stiefenhofer *has been employed at the De Beers Group for the past 22 years in a variety of roles from Exploration to Mineral Resource Management. He is now responsible for project assurance and review input for both the geology and resource estimation disciplines in the De Beers Group worldwide. His areas of expertise include kimberlite geology, mantle petrology, geochemistry, vulcanology, resource classification, project assurance as well as resource estimation.*

Martin Robert *has worked in kimberlite exploration and resource development for 15 years with the De Beers Group of Companies. He is currently based in Botswana with Debswana as the Group Geology Specialist.*

Anthony Revitt *has over 25 years of exploration experience in sub-Saharan Africa during which time he managed exploration programmes in Botswana, Tanzania, Zimbabwe, South Africa and the DRC, resulting in the discovery of kimberlites in several of these countries. Most of this work was done for the De Beers Group and he is presently operating as a private geological consultant.*

Renato (Spaggs) Spaggiari *has worked in the diamond industry for over 30 years in major and junior companies, and as an independent consultant. His experience covers all facets of exploration and project management, mainly in diamond placers in western, central and southern Africa. He obtained his PhD on the study of diamond distribution in marine deposits.*

John Ward *is a field-oriented geologist with some 38 years interest in the post-Gondwana and Gondwana record of southern and central Africa, in particular where this relates to alluvial diamond deposits and their primary sources. He has worked for a Geological Survey, the De Beers Group, several juniors and is currently an independent consulting geologist.*