OUR JWANENG STORY

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INTRODUCTION

When Leon Daniels first contacted us, and others, about the Botswana Diamond Exploration Conference 2017, he wrote: ‘The future of diamond exploration lies in us “old-timers” who have retired or are about to retire to inspire the next generation to go out there and make the next discoveries so vitally important for Botswana.’ Sadly, in presenting on behalf of both Stuart and I, I had to own to being one of those old-timers!

One of the sad facts of history has been that the discoverers of the Jwaneng kimberlite have never received the same recognition as those for Orapa. This is said with no disrespect to Dr Gavin Lamont, Jim Gibson and Manfred Marx – the Orapa kimberlite discovery in Botswana deserves all the recognition that it has always received. This disgrace cannot alter the economic success since the mine opened in 1982 after some nine years of evaluation and construction. Debswana (2017) states that 2015 production was 7.87 million tonnes of ore from which 10.408 million carats were recovered at a grade of 132 carats per hundred tonnes. Although the value is not reported, it was noted that Jwaneng contributes 60 to 70% of Debswana’s total revenue from all mines, including Orapa, Damtshaa and Letlhakane.

In contrast to the Orapa discovery, there was an absence of media reporting of the Jwaneng diamond discovery until Harry Oppenheimer stated in the late 1970s that ‘Jwaneng is probably the most important diamond discovery since Kimberley in the 19th century.’ This came after significant changes within the original De Beers Botswana Mining Company such as the opening of the Letlhakane mine, a production increase at Orapa and the informal adoption of the name Debswana (later formalised as Debswana Diamond Company). At the Jwaneng Mine opening in 1982, former President, Sir Ketumile Masire said: “Jwaneng Mine is not just any new mine but a true prince of mines - a gem in the world of gems”.

De Beers and Debswana to this day persist in showing the Jwaneng discovery as 1972, whereas the Jwaneng Mine 2424DK2 kimberlite was discovered in February 1973. 2424DK1 had been found the previous year, but there was a hiatus in exploration while the challenge of the thickness of the Kalahari sand cover was considered. Another date inconsistency is that in his discussion of the Debswana Joint Venture, Mr Blackie Marole (1988), the then diamond advisor in the Ministry of Mineral Resources and Water Affairs, stated ‘Shortly after the establishment of the Letlhakane Mine, a further diamond bearing pipe was discovered at Jwaneng.’ In reality, the Letlhakane Mine was established in 1975, some two years after the Jwaneng discovery.

We do not wish to give recognition to all those reports and references that are in error. Suffice it that we limit reference to the De Beers (http://www.debeersgroup.com/en/our-story/our-history.html#1960) and Debswana (http://www.debswana.com/Operations/Pages/Jwaneng-Mine.aspx) websites that both perpetuate this historical inaccuracy which can only be explained as noting the year of the first discovery in the Jwaneng area, and not the discovery of the Jwaneng Mine kimberlite pipe. It is strange that this should be the case when we are well aware that the Orapa 2125AK1 kimberlite was not the first discovery in northern Botswana in 1967; that honour goes to 2125BK1, to the north of Letlhakane.

The paper by Janse and Sheahan (1995) is an otherwise important worldwide catalogue of kimberlite occurrences that strangely reports 1975 as the discovery year (as did Marole, ibid). In contrast, it is heartening that at least two well-known books about diamonds provide the historically accurate discovery date of 1973 (Bruton, 1979, Wannenburg and Johnson, 1990). The definitive statement on this piece of history is provided in the first compilation of the Geology of Botswana (Carney, Aldiss and Lock, 1994. p94.). This Botswana Geological Survey Bulletin must be acknowledged and accepted as the prime reference in regard to the discovery date for the Jwaneng Mine kimberlite pipe.

We have always emphasised the team effort that in the words of Isaac Newton allows us to ‘see farther by standing on the shoulders of giants’. Dr Lamont’s memoirs make clear the contributions of several geologists over a number of years from the early work of Mike Whatley in 1969 to the discovery drill hole in 1973, and beyond (see discovery timeline Figure 1).
Fairly apportioning credit among the many geologists, and others who worked on the project would have been problematic, though the discovery drillhole marks a point in time. A comprehensive list of technical personnel involved from 1969 until mine opening in 1982 is provided in the Acknowledgements.

Both Stuart and I were new geology graduates when we joined De Beers Botswana Prospecting in 1970 and 1972 respectively. This timing must be seen in parallel with at least two iconic diamond exploration milestones:

- Clifford (1966) illustrated empirically the association of diamondiferous kimberlites with cratons stable since 1,500 Ma. Although Clifford had nothing to do with the naming of this observation, it has been adopted as Clifford’s Rule in the diamond industry. It still largely stands the test of time but is not known to have contributed in any way to the Botswana diamond discovery successes.

- Dawson and Stephens (1975) studied garnet compositions from myriad published analyses with statistical cluster analysis. Cluster 10 comprised 50% diamond-inclusion garnets and 50% garnet xenocrysts in kimberlite. Although a prior paper (Gurney and Switzer, 1973) had demonstrated the relationship between xenocrystic high-Cr and low-Ca garnets, and similar diamond inclusion garnets, it is the G10 garnet that has become the most important indicator mineral for diamond exploration through the 1980s to the present day. Although this milestone post-dates the Orapa and Jwaneng discoveries, it was known that mineral chemistry was an important potential new exploration tool.

**THE DISCOVERY PROGRAMME**

Dr Gavin Lamont was the Country Manager for Kimberlitic Searches, subsequently De Beers Botswana Prospecting from 1955 until his retirement in 1979. He was informally well-known as “Doc”. He wrote ‘I decided to try some soil-sampling on either side of the road that goes out from Lobatse to Ghanzi where the sand-cover is relatively thin. Jim Gibson and Jim Platt carried out this work but nothing of interest was found in their samples although they worked to within some twenty kilometres south of today’s Jwaneng mine, and they certainly covered ground where there are small kimberlitic garnets in the “halo” of indicator minerals that surrounds the Jwaneng group of kimberlites. This was the first time that we had moved into the Kalahari environment and our sampling methods in those days could not cope. That is how we missed Jwaneng in 1962 … ’ (Lamont, 2001).

Lamont (2001) continued ‘In 1962 Jim Gibson and Jim Platt were still using the gold pan to concentrate their
soil-samples and that is certainly why they missed the 1-millimetre and smaller garnets from the Jwaneng pipes halo’. Lamont also commented how different history might have been if Jwaneng had been found before Orapa. We have no indication what thoughts may have been in Lamont’s mind, but we would make the following two points that would surely have had significant possible consequences if the Jwaneng kimberlite had been found in 1962:

- Pre-Independence Botswana was a very different place to the Independent country we know today. For example, there were elements of the then European Advisory Council who still advocated for the incorporation of the Bechuanaland Protectorate into the Republic of South Africa. This was in spite of the Winds of Change speech of British Prime Minister MacMillan in 1960.

- One of the first post-Independence Acts of Parliament was the ‘Mineral Rights in Tribal Territories Act’ under which the various tribes voluntarily ceded their ownership of mineral rights to the new State of Botswana. This simple act of cession has allowed Botswana to avoid the challenges of many other African countries in the post-Independence era. Lamont correctly hypothesised that bioturbation by white ants (termites) would transport Kimberlite Indicator Minerals (KIMs) to surface in areas covered by Kalahari sediments. Bioturbation is the disturbance of loose sedimentary deposits by living organisms and is not limited to activity by termites. However, it is their thirst for moisture which is the feature of their burrowing that has been identified as the driver for excavations down to the water table.

Lamont (2001) wrote ‘Some years after I retired I paid a visit to Jwaneng and by that time the open pit was well developed. Around the sides of the pit the interface between the kimberlite and the overlying fifty metres of Kalahari sand and other sediments was exposed, and there we were able to see a few small fossil tunnels that had been made hundreds of thousands of years ago when the first miners at Jwaneng, the termites, burrowed down to get moist clay with which to build their large mounds at the surface; in bringing up moist clay from the kimberlite, they also brought up the small kimberlitic garnets and ilmenites, and it was these mineral grains that our soil-sampling programmes found and that led us to the Jwaneng pipe.’ In the early 1980s, we both observed similar termite tunnels in the underground sampling development drives. It is probably important to comment that bioturbation was, and is, never a one-step process. It is incremental and cumulative over geological time. The surface KIM anomaly may well become weaker with the thickness of sand cover.

Lamont (2001) wrote ‘It is of interest to mention that in the Tuli Block in 1955 I devised the continuous scooping method of soil sampling to cover the interfluve areas between the drainage lines. When I demonstrated this new sampling method to Arnold Waters he was not particularly impressed and he called it “the lame duck method” because every ten to fifteen paces the man taking the samples stoops down to scoop up some soil. Anyway it was thanks to this soil-sampling method that we eventually found Orapa and Lethakane and then Jwaneng.’ One can now comment that this was very far from being a 'lame duck' method. However, there were concerns that the surface disturbance by cattle, hartebeest and wildebeest might negatively impact this sampling technique in the Jwana area.

Of passing interest, to quote from Lamont (2001) ‘It was not only the wildebeest and hartebeest that passed through the Jwaneng area. In the early Orapa days we sometimes saw elephant spoor. No one expected an elephant near Jwaneng, but one had decided to trek away to the south out of its normal habitat and Stuart actually saw its spoor not far from Jwaneng. I believe that it kept on going south and eventually crossed the Molopo into South Africa where it was shot by a farmer when it was drinking out of a water reservoir on his farm.’

Manfred and Jim used RSS, DSS and DGL sampling techniques in their lead-in to the Orapa-area discoveries starting with 2125BK1 north of Lethakane. They are all based on baselines oriented N-S or E-W and separated by 5 miles (latterly metricated). There was a sample spacing reduction from RSS to DSS and DGL depending on positive results from the previous phase. Although the exact locations of samples were not known, the relative positions were closely enough constrained for future discoveries to be locally understood and properly surveyed eventually.

Mike Whateley (Figure 2), and other geologists including Bruce Lynn and Keith Huxham completed RSS in 1969. Lamont (2001) wrote, ‘By the end of the third quarter of 1969 the Anglo American Research Laboratories...’
reported the first definite and probable ilmenites from reconnaissance soil-samples taken over 150 square miles across the Kweneng/Ngwaketse boundary, and these ilmenites are therefore considered the first indication of the Jwaneng kimberlite province.

Whateley left De Beers Botswana Prospecting in 1971. Norman’s personal history included assisting Huxham in this programme around and south of Molepolole before returning to Leeds University in mid-1969. DSS and DGL were undertaken in 1970. DGL was completed in 1971 over four KIM anomalies - Malan 1 (DK1), Malan 2 (DK3), Lynn’s Luck (DK4) and Whateley’s Wish (DK2) (Figure 3).

An aeromagnetic survey (Figure 4c) was only flown later in 1974, after the Jwaneng discovery. Although DK1 was reasonably clear as an anomaly, DK2 only showed as a flat domal feature that arguably would not have been recognised on its own.

The first of the Jwaneng kimberlites, 2424DK1, was drilled and discovered by Peter Bickerstaff in 1972. Figure 5 shows the Holman tractor-mounted, down-the-hole hammer VOLE drill first used at Orapa and then relocated to the southern Kalahari in 1972. It was limited to 120 feet depth, and thus technically not capable of reaching 2424DK2 at over 40 m depth.
Drilling of Whateley’s Wish (the future DK2) by Bickerstaff and others may have been miss-located but in any case did not drill deep enough in 1972, and thus 2424DK2 was not found at that time. Two prospecting pits to 35 m depth were sunk by Bickerstaff on DK1 in 1972 using the headgear previously used in the Orapa kimberlite evaluation programme in 1969-70 (Figure 6).

Representative samples were transported to Johannesburg and treated at the De Beers Diamond Research Laboratory (DRL). Botswana Mining Law limited the depth of surface pitting/trenches to 120 feet (37 m). DK1 was shallow enough for this sampling method as had been used at Orapa, but the results were entirely negative for diamonds. Subsequent to the negative results from the DK1 discovery in 1972, there was a hiatus in field work while Lamont conducted an internal review and reassessment of Whateley’s work and results. This reassessment recommended a renewed work programme; repeat sampling by Stuart’s team commenced in late 1972. Lamont reported that ‘We carried out a magnetometer programme without much luck because, as we eventually found out, the Jwaneng pipes mostly have weak magnetic signatures.’

Although the Scania vertical field magnetometer was used in 1971/72 to define the DK1 kimberlite, a Geometrics proton precession magnetometer was used for the first time in Botswana over Whateley’s Wish in early 1973 by Norman and Tabona Machinya. A broad domal total field anomaly was revealed which was later duplicated with the aeromagnetic survey. A weak gravity anomaly similar to DK1 was surveyed after the discovery drilling. Although the magnetic anomaly was very weak, it did fit well with the new sampling results. Unfortunately, we do not have these results of the new sampling and magnetic survey data. However, there was one very important feature of our work that was an innovation over previous results. Lamont recorded that ‘Norman made a statistical study of all the sampling information using a mean-squares method and this indicated targets for drilling that were hopefully above pipes beneath the sand-cover.’ Actually, it was a very simple four-point moving average, but the result would have been very similar to the average obtained using a mean squares algorithm. It was based on reading a Witwatersrand Basin paper by Des Pretorius while a student (Pretorius, 1966).
If you examine the simulated raw data in Figure 7a, it can be seen that adjacent grain counts may jump from zero to over a thousand and then back to low counts. This was the feature of the actual data that was very confusing for the original plots and interpretation. The moving average (Figure 7b) removed much of that uncertainty.

Figure 7b. Simulation of 1973 sampling results: 4 point manual moving average of simulated data.

Figure 7c displays the result that would be achieved today with modern computer graphics software. Ratie April Ikothaeng (Figure 8) was the driller for the Jwaneng discovery hole. Figures 9 and 10 show Norman at the discovery hole in February 1973.

Figure 8. Ratie April Ikothaeng operating the Holman tractor-mounted, down the hole hammer VOLE drill.

Figure 9, photographed by Stuart, might have been the Jwaneng iconic discovery photo equivalent to the Gibson, Lamont, and Marx picture over the Orapa discovery pit. However, the optics of a long-haired ‘pot smoking hippie’ would not have made for good PR in those days. The drill chip samples (Figure 10) were

Figure 9. Norman Lock examining drill chips from the 2424DK2 discovery hole, February 1973.

Figure 10. Drill chip examination at the 2424DK2 discovery hole, February 1973.
concentrated using a simple hand-operated Gerryts jig that had been designed by Bert Gerryts in the 1950s as a substitute for other methods of concentrating loam samples.

Whilst further work at 2424DK2 was underway, outside exploration continued which led to the discovery of: 2424DK3, DK4, DK5, DK6, DK7, DK8, DK9, CK1 and CK2 (See Figure 3) by Stuart and other geologists in his team. Soon after the Jwaneng discovery, Lock moved to Kokong and then to Letseng Mine, in Lesotho. Stuart stayed at Jwaneng and supervised the whole of the evaluation programme (see below) through to mine opening in 1982.

THE EVALUATION PROGRAMME

The Naledi valley, within which the Jwaneng 2424DK2 kimberlite is located, was a broad very shallow grass-covered fossil valley. A small rural community was domiciled around the low Jwana Hill where a single water borehole sustained the cattle post, and helped De Beers in the early days of exploration. Lamont wrote ‘Stuart then took over the drilling programme around Norman's kimberlite intersection, and as the pipe got bigger and bigger we knew we were really onto something significant.’ Lamont continued ‘It was clear that we needed much heavier drilling equipment to cope with the Kalahari sand-cover, and I thought about the percussion "jumper" drills that Jim Gibson and I had used in the early days at Orapa to drill the first water-supply boreholes.’ The standard jumper drill bit for water boreholes was 4½ inches, but specialised bits for this and future sampling programmes were progressively increased in size to 24 inch.

Initial outline drilling of the 2424DK2 kimberlite was supervised by Stuart using the VOLE drill. A series of holes were drilled along the assumed long axis of the kimberlite at 100 m intervals. This assumed long axis was interpreted from gridded and contoured soil sampling KIM counts and the ground magnetics. This series of holes gave the rough dimensions of the South and Central Lobes of the tri-lobate Jwaneng pipe, with an overall size of the order of 900 m by 500 m.

A great deal of difficulty was experienced using this depth- and power-limited drill in penetrating the Kalahari overburden. Clearly this method of delineation was problematic and limited to shallow depths. Indeed it is our memory that a whole drill string was lost in one of the early holes, at great expense. One can speculate on our job security if that had happened before the discovery hole.

Due to the apparent size of the kimberlite, it became clear that the team would be working the project for a considerable time and the need for a water supply to replace the supply from the Jwaneng Village borehole sited at Jwana Hill became critical. In all, some 6 water bores were sunk around the margins of the pipe which supplied water to the geological and development operations until the Northern Wellfield came on stream in December 1979.

The advantages of the jumper drill rigs were:

- The low-cost per m
- A simple construction, low-cost and ease of maintenance and repair.
- A larger sample available from the 6-inch or 8-inch hole size in comparison to the 4-inch Vole drill

The disadvantage was:

- A slow penetration rate of ~10 m per 8-hour shift compared to the Vole drill.

The holes were cleaned of drill cuttings, essentially a slurry of water and kimberlite, by a dart or flap valve bailer into half drums in one-metre sections. Initial testing of the kimberlite for diamond content was by drying these cuttings over an open fire and shipping the material to the AARL/DRL laboratories in Johannesburg. (None of these results were ever conveyed back to the geologists on the ground. The silo secrecy management approach). All of the initial holes drilled on the margin of the pipe for outlining purposes were in hindsight too shallow and revealed little insight into the dip of the wall rock contacts. It must be remembered though that the objective of this initial work was to determine the sub-crop wall rock contacts of the kimberlite. This work was in progress from 1973 to 1975.

Evaluation Drilling

In 1974 methods to obtain quantities of kimberlite for treatment for diamond grade, were discussed. Due to the Kalahari overburden thickness and without expensive shaft construction and headgear, it was not possible to sink shallow prospecting shafts to evaluate as had been done at Orapa. One or two shafts with horizontal drives would also not have provided the information required for vertical and horizontal diamond content determination. The only alternative was preliminary evaluation by drilling.

Large diameter water flush drills (Wurth) were excluded due to their appetite for large quantities of water. It was therefore decided to use the Prinsloo Harvester cable tool
Drills on-site as well as additional beefed up versions and equip them with larger than standard drill bits. Other modifications were reducing the length of the drill string to reduce weight, increasing drill string diameter from 4.5 inches to 6 inches for added strength and utilizing 15
inch chisel bits. Contractors were used at first, but as the drilling crews gained experience with heavier strings, more and more drill rigs were purchased.

The initial 30 x 15 inch holes were drilled at 100 m line spacing and 200 m hole spacing to 150 m depth. It was inferred that the Jwaneng kimberlite was a primary body from the small amounts of core available then, and that it was fairly homogeneous. Thus it was anticipated that the diamond content would also be fairly uniform throughout. This was not so. After these initial holes had been drilled, it became evident that the kimberlite contained diamonds in potentially significant economic quantities and late in 1976 proposals for bulk sampling by underground development were drawn up. This would have taken four years to complete, and the plan was rejected by the Botswana Government advisors at the end of March 1977 as too time-consuming.

The drilling method was not demonstrated at the time and threw up a number of data integrity issues. It would have been scientifically more satisfactory to have followed the underground bulk sample process. Diamond recoveries showed that the Central Lobe was the richest area and the South Lobe less so. There was very poor grade correlation between sampling drill holes. Closer spaced sampling data was required. Holes were then drilled to form a 100 m sampling grid to 200 m depth and finally at 50 m centres for mineral resource/ore reserve block estimations. The latter encompassed the North East Lobe as well. Drill sampling by jumper drills was completed in 1982. Poor horizontal and vertical grade correlations and other issues persisted.

**Sample Processing**

The DK2 15-inch jumper drill sample comprised highly comminuted sludge. The sludge was classified into three fractions 0.5-1.5; 1.5-4; >4 mm) using Sweco screens. The dry weight was measured by taking a subset sample wet, drying this in an oven and then recording a dry sample weight. Density calculation was by water displacement which was surely only a first approximation of the true bulk density.

The average weight for the 5 m drill samples was 1.5 tonnes. The volume of the material removed was calculated using a down the hole caliper logger. Each hole was logged after each 5 m section drilled. Caliper log information showed considerable break-back and contamination of lower levels from the less competent oxidised and reduced upper tuffaceous pyroclastic/debris flow horizons.

The two smaller classified size fractions were concentrated by Plietz jigging. The +4 mm fraction was transferred directly for milling. The two small size concentrate fractions were combined and milled for a short time in neoprene lined mills using ceramic balls. The larger size fraction was milled separately. Milling was required for pre-conditioning of diamonds prior to recovery over grease. Sorting was conducted on site, and the diamonds weighed, recorded and dispatched by road to Gaborone for valuation and royalty payment. Sample tailings were submitted to DRL in Johannesburg for locked and refractory (to grease recovery) diamond recovery.

Over 200 holes were drilled producing 5,000 tonnes of kimberlite (Figure 11). The work resulted in the delineation of about 90 Mm³ of kimberlite for the 54 ha surface area. This project was the first fully 3-D “resource” by De Beers. The sampling data at Jwaneng was down to 0.5 mm diamond size and thus overlapped with the micro-diamond size range. However, factorisation to larger bottom cutoffs was undertaken for practical production purposes.

**Further Testwork and Resource Estimation**

Shaft samples were also recovered for metallurgical test work and to build a larger diamond parcel for valuation. From the beginning of 1978 samples were obtained from shafts, three in the Central Lobe, two in the South Lobe, and one in the North East Lobe. This bulk sampling provided material for:

- Metallurgical test work
- Geology and emplacement model concepts
• Comparisons of diamond release from shaft and drive samples with that of highly comminuted drill slurry. For this latter purpose 3 – 15-inch holes to 200 m were drilled around each shaft.

Initially, the material was treated in rotary pans (shafts 1-4) with final recovery by jigging, milling and grease recovery. Once the Bulk Sample Plant was completed and commissioned, shaft material from shafts 5 & 6 was treated by conventional DMS and X-ray recovery. From selected horizons, 20 tonne samples were sent to DRL for metallurgical test work. In summary, 6 shafts were sunk to 200 m depth with horizontal developments at 75m and 150m levels. Several thousand tonnes of kimberlite were recovered. A typical selection of recovered stones is shown in Figure 12.

Figures 13 and 14 may be somewhat simplistic compared with today’s knowledge. However, this was the understanding of pipe morphology, and overburden lithology and stratigraphy in 1979.

The sampling data were passed to Tinus Oosterveld in Kimberley for mineral resource estimation using Ordinary Kriging. This was the first time that De Beers had cumulated a sample database to support a full three-dimensional resource estimate. However, this was not the first time for a kimberlite – the Camutue kimberlite in Angola was drilled using a crude fluid reverse circulation drill in 1969 providing a similar 3-D sample database.

The estimation challenges at Jwaneng that required several ‘fudge factors’, included:

• Sample Size
• Downhole break-back contamination
• Shafts not representative of the whole orebody
• Differences in treatment methods and efficiencies between jigging/grease recovery and rotary pans/DMS/X-ray
• Possible diamond breakage by drill
• Density variations with depth
• MTP crushing to 25mm rather than 12mm used to feed rotary pans, and intense comminution of drill samples
• MTP lower cut-off of 1.65mm vs 0.5mm for drill samples and rotary pans
• Poor understanding of the ore body geology and emplacement mechanism
• Diamond security could also have been better

The results supported a very positive outcome and the decision to build a mine.

CONCLUSIONS

It is generally acknowledged that Jwaneng is the world’s richest diamond mine. Its position within Debswana alone is exemplified by the value contribution of some
60-70% of all the Debswana mines combined. One might add the other non-Debswana mines, and the conclusion would be the same. Published future mine planning for Cuts 8 and 9 will extend the open pit to some 850 m below surface over the next 20 years. It is not inconceivable that Debswana will still be mining Jwaneng well after 2050 (Figure 15). It is safe to predict a future underground mine to perhaps 1,000 m depth and the life of mine exceeding a century since discovery or even mine opening.

**Figure 15. Google Earth view of Jwaneng Mine today.**

**ACKNOWLEDGMENTS**

We wish to acknowledge here a comprehensive, although possibly not exhaustive, list of the management and technical team members who contributed with their skills during the discovery and evaluation programme from 1969 till mine opening in 1982:

Management:
Dr Louis Murray, Dr Gavin Lamont, Gus Edwards.

Geologists:
Mike Whateley, Keith Huxham, John Keenan, Bruce Lynn, Peter Bickerstaff, Stuart Vercoe, Norman Lock, Simon Price, Franco Bonavia, Mike Foster, Pat Foster, Steve Eastell, Pat Bartlett, Tim Brewer, John Wood, Alistair Lamb, Roy Irving, Don Duncan, Tony Leach.

Field Officer/Team Leaders:
Simeon Muniazo, Moses Rapoo, Tabona Machinya, Moses Namati, Graham Lisamore, Ross Malan, Jasper Mortimer, Kevin Baron, Duncan Campbell, Andrew Murray, Rocks Malapela, Brod Malema, Eleven Malema, James Moreti, Isaac Toromba, Ramoosi Malapela, James Ramatlopi, John Segobye, Reg Penfold, Alan Town.

Drivers/Cooks:

Miners/Drillers:

One thing that Stuart will always remember was the speed and efficiency with which development took place once the green light was given in 1978. The peace and quiet of a bush camp had gone forever. The Mining, Civil and Mechanical Engineers, Administrative Staff, Contractors, Catering, Procurement, Security, Medical and Teaching Staff (as well as the Geology Dept), Botswana Police Service, all worked extremely long hours under difficult conditions to achieve the preproduction deadlines. Thanks should go to Mike Smith, the first designated Mine Manager, and his predecessor John Walls.

**References**


