

# Contributions to Gemology

Record-breaking rubies discovered in Didy, Madagascar  
在马达加斯加Didy矿区破天荒发现红宝石



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# Record-breaking Discovery of Ruby and Sapphire at the Didy Mine in Madagascar: Investigating the Source

By Dr. Adolf Peretti, FGA FGG and Lawrence Hahn, GG  
 GRS Laboratories (<http://www.gemresearch.ch/video/Didy5.htm>)

In May 2012, the GRS lab in Bangkok received two very large, high-quality rough ruby crystals (Fig. 1A) for testing from a client who had flown straight to the lab from Madagascar.

The concerned client had heard rumors swirling about in Madagascar that the crystals were synthetic, and that he needed confirmation of their authenticity before his group would proceed with further investments.

Laboratory testing with ED-XRF, FTIR, UV-VIS, Raman and microscope of the specimens confirmed that the huge crystals were indeed natural and unheated. To link these crystals to the mine in question for their client, the authors undertook a perilous field trip to the source of the crystals for a first-hand inspection of the mine site. By documenting the gemstone rush on video and collecting rock and mineral samples from the site for comparison, they would be able to decode the geological conditions under which this corundum deposit was formed.



Fig. 1A, B: A gem-quality rough of over 60 carats from Didy (Madagascar) is faceted into an over 26 carats of magnificent ruby (right). World record prices were paid for such magnificent rubies, initiating an enormous buying rush. All pictures are by the authors Peretti and Hahn and copyrighted by GRS if not otherwise noted. (<http://www.gemresearch.ch/video/Didy4.htm>)

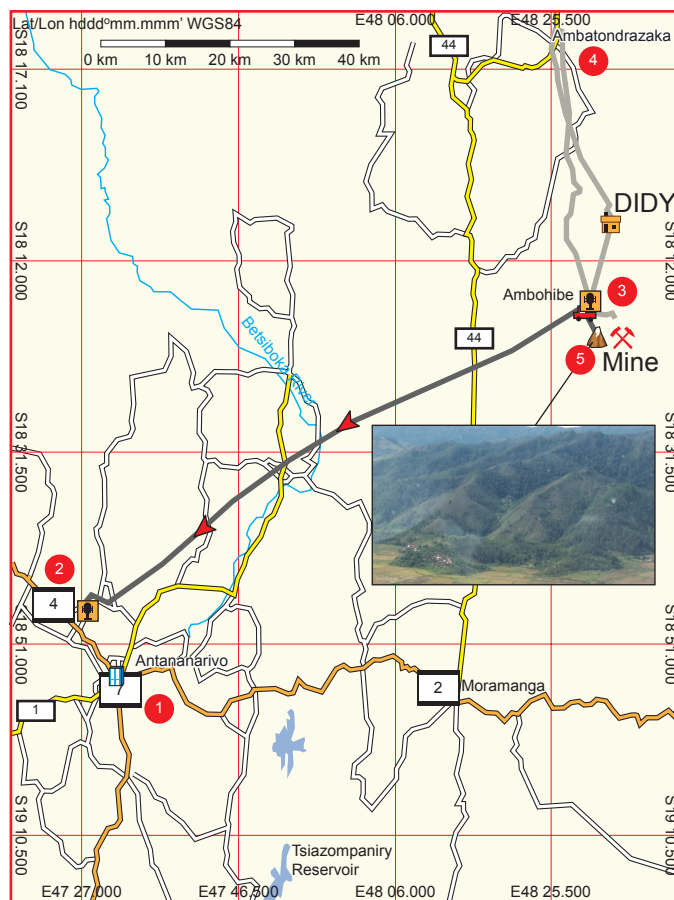


Fig. 2: A section of the detailed flight map to the mine by helicopter as recorded by our own GPS; 3-4 Good weather flight from Ambohibe to Ambatondrazaka navigated by Peretti when the board computer crashed. (Fig. 5) 4-3 Bad weather flight following terrain to Ambohibe without use of GPS; 3-2 return flight to the capital bypassing the rainforest (1 is the capital Antananarivo).



*Fig. 3: A memorable snapshot of the authors Peretti (left) and Hahn (right) after returning from the expedition to the Didy mine. The expedition material exceeding 150kg that returned back included a portable gem lab and camping equipment. The authors are barefoot after the strenuous 16.5-hour jungle walk to the mine and back; their feet are sore and the mountain boots are drenched by mud. (Photo: Cushman. © GRS.)*

They would also acquire critical ruby and sapphire samples for further study (Fig. 7A and cover page). Every field trip like this one in Madagascar carries safety risks, logistical challenges and often, delicate negotiation with local residents and the government. Getting there was the first of a series of challenges. As Peretti recalls, "It entailed 12 hours by car to Ambatondrazaka (Amba) followed by a 3- to 5-hour drive to Didy, weather permitting; finally, foot travel for at least a day. Still there was no guarantee of success in this unknown territory in the midst of a seemingly protected and impenetrable rainforest to the north-east of the capital." Hence, Peretti determined that air travel was the better option, and enlisted a former local gem dealer to arrange for a helicopter flight out of Antananarivo over the apparent national park to locate the mine and plot definitive GPS coordinates. They would determine the nearest landing site, continue to Didy for authorization from the local government for clearance to the destination, and then commence the journey somehow. A 400-liter re-fueling deposit in Amba was organized by the aviation company. They were accompanied by a helicopter technician in the 12-hour drive to Amba in tandem with their departure from Antananarivo (Fig. 2)

Excerpts taken from Peretti's expedition diary reveal the spellbinding drama that unfolded during the field trip.

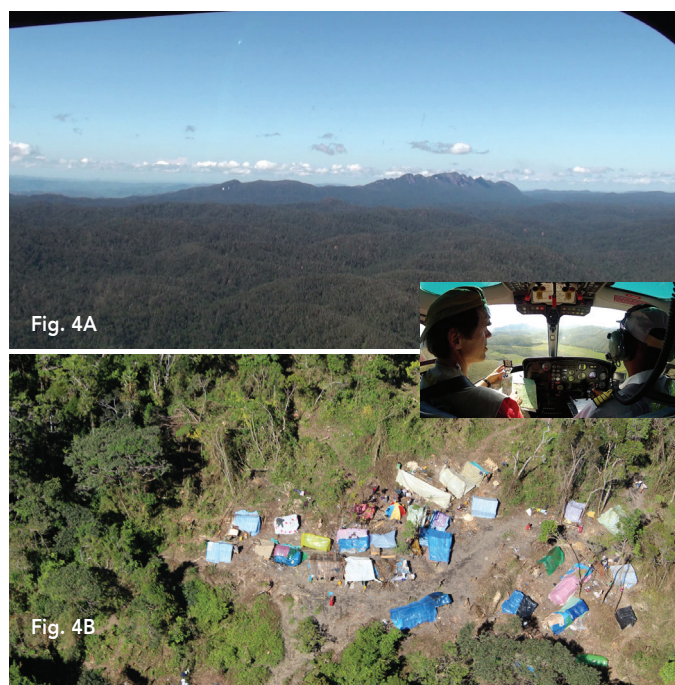
### Monday, May 14, 2012

Late information reached the GRS Laboratory that the mine,

with an estimated 30,000 miners, was sealed off for non-locals by the government, and that it is a 3-hour walk from the nearest village. Roadblocks set up by locals or government authorities, heavy rains or adverse road conditions would have compromised our road trip, which requires nearly a 15-hour drive from Antananarivo, known as Tananarive Capital, to Didy the nearest town to the mine.

### Wednesday, May 16, 2012

Zahamena-Ankeniheny, the forest corridor where the mining was supposedly occurring, is not yet a national park but has



*Fig. 4A: Granite rocks 10km south of the mines form a mountain range (more resistant to weathering). (See Fig. 17 for geology).*

*Fig. 4B: An aerial photo by GRS from the mining camp at Didy (Madagascar) when overflying the protected forest of Zahamena-Ankeniheny (inserted picture, Peretti taking over the navigation as onboard GPS computer crashes).*

been proposed for protection. Referred as a national park, it is earmarked for such classification to prevent its desecration like the protected areas.

### FLYING OVER THE NEW MINES

<http://www.gemresearch.ch/video/Didy1.htm>

Soaring over steep cliffs blanketed by rainforest. The panorama was breathtaking (Fig. 4A). After 40 minutes of flying, the pilot announced that we had reached our GPS coordinates. An assembly of people on the ground came into view (Fig. 4B). The sapphire area called Didy is officially named Ambatovolona.

Circling the mining area following a riverbed, miners were seen digging and washing. Almost everyone on the ground stopped working to stare at the helicopter. A second smaller place we spied suggested that miners were expanding to different areas now. Witnessing hundreds of blue tents, we wondered how many miners were actually there. It did not appear to be a 30,000-miner campsite as previously speculated; but more like 5,000 to 10,000 miners. This was no organized mining effort. It was a first-come, first-served operation led by a large number of individuals.

After circling several times, Peretti signaled the pilot to abandon the area. The images and video footage captured were sufficient, and we did not want to disturb the miners any further. We looked for the closest landing site. Past some small mountains, the mine spanned about 5km to 10km inside the rainforest, and yet, no landing site near the mine seemed possible. Then we spied small groups of cars parked at the forest edge, most likely gemstone buying agents. Then we discovered a small hill with a steep road surrounded by a half dozen houses, like a medieval village fortified on a hilltop. We called it the Eagle's Nest, and later found out that it's actually named Ambohibe.

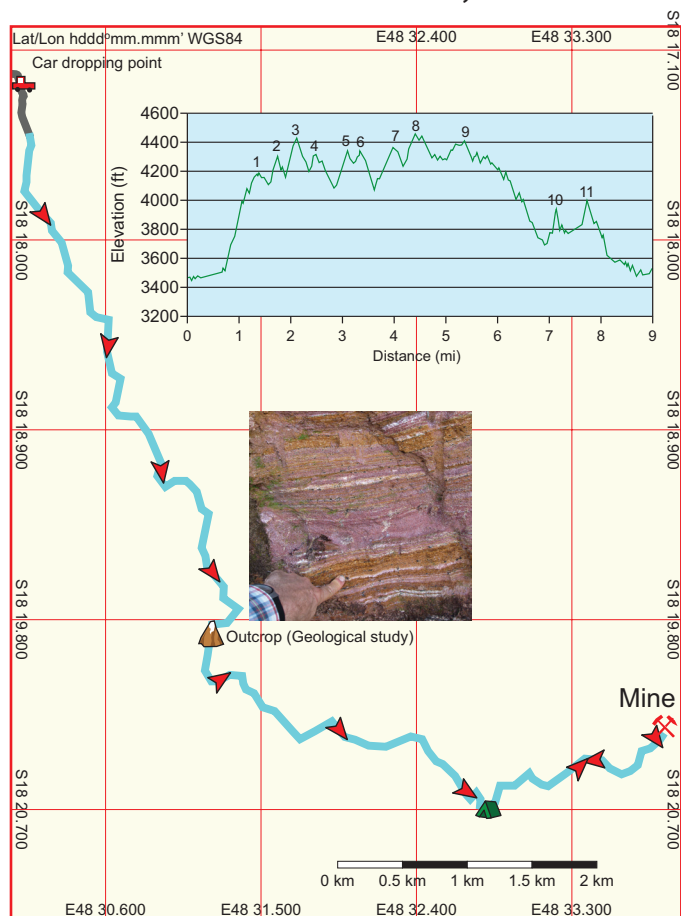
The nearest possible landing site was about an 8-minute flight from the mine next to the Eagle's Nest. We discovered a harvested rice field with hardened earth and a few cows. We made a test landing there, saving the GPS coordinates for reference. There, we studied the environment before going on to Didy.

Landing at Didy, a throng of charming children met us and a large crowd appeared relatively subdued. They acted respectful and obedient to the local elders. Surely, it was the first time these kids had seen a helicopter. The village mayor explained that all able-bodied men were now mining in the forest, leaving the hard work at the rice paddies to the women, resulting in a low harvest this year. We negotiated an important written permission by the local government to visit the mines.

Then arriving in Ambatondrazaka, a reliable source that had been contacted before the trip offered us a fine lot of small rubies and sapphires for our reference collection. When we examined some large ruby and sapphire specimens using a portable lab (Fig. 24), we realized the mine does exist, and was producing large, unheated vibrant stones. Our anxiety grew as we contemplated being able to make it to the mine. That may be too much to hope for we thought. "Single-day trips to mines are never enough for serious geological field work, and would this mine prove to be a short-lived flash instead of a real rush?" We received a valuable tip, "Buy cigarettes for the miners." Peretti had recalled that the miners in Ilakaka, working far from civilization, always asked the same question, "Cigarettes?" especially when being photographed or filmed. They expected royalties.

## Thursday, May 17, 2012, 8am

**FACING A HOSTAGE SITUATION** After circling around low clouds, we finally made it to a landing spot. Locals on the ground seemed dangerously hostile, grim-looking folks. They had encircled us and their Land Cruisers had blocked our exit route. A non Malagasy national dealer said, "The local 'chief' is asking US\$1,000 for landing rights and US\$2,000 as passage tax," disregarding our authorization letter from Didy. We were already there with the helicopter and completely surrounded. We agreed to not comply with their "offer." Further negotiations reduced the "offer" to US\$1,000, breaking the impasse. We started our march from a point we christened the "Car Drop-off;" the furthest point a vehicle could reach (Fig. 5). This parking outpost gathered various 4-wheel drives, crewed by an assembly of local gemstone buying agents. We were met with hostile and sullen stares until they realized we were



**Fig. 5: GPS tracking of the walking route through the jungle to the mine, including the marched elevation profile. Note first steep climb and the crossing of about 14 small mountain peaks (hills) on the way to the mine. Red arrows mark stops for drinking water and eating in approximate one-hour intervals. Trail inserted in geological map (Fig. 17)**

non-threatening. A driver we pre-arranged to pick us up there the next day disappeared, never to be seen again.

**THE EXPEDITION ON FOOT** We commenced our 16-and-a-half-hour walk after programming the coordinates of the mine and this landmark entry point into our GPS. We also took a guide and four porters for our equipment containing tents, food reserves and water, but we carried our camera equipment.

At first, we covered a good distance, moving at about 6km per hour. We gained confidence, following a small stream running through the valley bordering on rice paddies. Further along, the path became more densely overgrown. We crossed two men carrying a massive wooden log, probably rosewood, and walking the opposite direction towards Eagle's Nest. The log looked like it had been stripped and formed in a factory within the protected rain forest, prepared and hand-carried for exportation. These illegal wood loggers had (probably) also discovered the gems in the first place.

Eugene, the guide, doubled as a bodyguard. Our hired staff needed some energy and prepared themselves by stopping for a rice and fish bowl at a nearby hut. This entry point to the protected rainforest had another group of buying agents that seemed unfit for the brutal walk, relaxing with radios in an improvised hut. We would endure seemingly endless mountain climbing; 200 meters up and down repeatedly. Eugene brought up the rear, ensuring that nobody got lost or injured. The mountain path went up and down, the overall tendency being upwards (Fig. 5 elevation chart).

### UNAUTHORIZED PROMOTIONAL HELI FLIGHT 11:34am, Ambohibe



*Fig. 6: A miner in deep mud re-supplying the mine with 30kg to 40kg of rice, oil, small river fish and cigarettes. The miner walked barefoot as regular shoes are stripped off by the deep mud.*

Upon returning home and studying the pilot's logbook, we discovered that 2 hours after leaving the landing spot, the helicopter crew boarded with an unknown person on the aircraft.

The helicopter took off from Ambohibe with instructions to return to Amba, but this time carried an unauthorized blind passenger aboard. The pilot logged everyone by first and last name, except the blind passenger identified by his first name "A." We assumed that the pilot was bribed. According to someone, he was the same 'chief' who had previously demanded passage tax. After the entire trip was over, the pilot acknowledged modifying the passenger list and the routing instructions without the financier's permission. The maverick group overflew the mines, taking pictures and tossing business cards from the helicopter. The unfortunate result of this ill-thought-out activity was that GRS lost exclusivity on documenting the scene, and every dealer operating in the mine was now alerted that foreigners could invade their working space. Those business cards signaled that the mine was about to go mainstream, which increased the risk. Was the crew easily influenced into doing something unethical for business gain? Were they coerced by A's influence and nobody wanted to talk about it, or was it an act of favor to "A" to secure a strategic alliance? Most likely the other non-Malagasy nationals had pre-planned this promotional farce to strengthen their buying power.

The helicopter had flown back and forth unnoticed by Peretti and Hahn. So, had the route been carefully chosen to avoid being discovered?

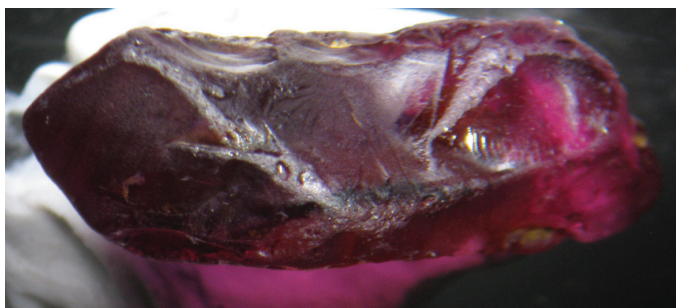
### IN THE JUNGLE ON THE TRAIL TO THE MINE Lunch break, noon

During the trip, we ultimately shared two-thirds of the rations with the porters and guide who brought no food along. They had a single bottle of water that they shared and refilled in streams (Fig. 8).

In sharp contrast to the white group, they hardly broke a sweat during the walk. They also carried heavier loads; but a lifetime in this searing climate had prepared them.

The terrain was becoming muddier, more overgrown and elevations became steeper; the speed was reduced to 2km per hour airline distance. A couple dozen friendly people crossed our path. We were asked several times if we had been circling with a helicopter. We explained that we were gemologists not journalists, and tourists not buyers. We did not know that they were referring to the helicopter they saw just hours before. Some asked if we wanted to buy stones, but we decided not to buy anything as we thought that showing money should be avoided at all costs. Not buying

permission to buy stones anyway, and we did not want to give the impression to Malagasy dealers that we were going to cut them out from their business. Some fellows who made offers were in reality agents who did not intend to sell us stones, but wanted to test us to see whether we were seeking gemstones. We stressed that we were Swiss and German citizens working for a private company. A rumor circulated that American journalists were coming – noticeably not welcome. Local miners and dealers were showing signs of distress over the repeated helicopter visits.



*Fig. 7A: A typical example of a 4-carat rough ruby from Didy. It's not a fragment but a completely preserved rough formed in the rock. Other minerals have formed simultaneously with the ruby and left different types of negative imprints. No signs are found for transportation by a river (no rounded edges and scratches). Blue color zoning in the stone is formed only on the side where it was exposed to interaction with minerals that must have contained titanium. (Hahn Collection).*



*Fig. 7B: On the left-hand side is an 85-carat rough Padparadscha sapphire that is completely clean and is estimated to exceed US\$1 million in value. Another example of a high-value faceted Padparadscha sapphire of 18 carats is shown in face-up and in profile position. This Padparadscha from Didy is loupe-clean, has perfectly mixed orange and pink color, is spared of thermal enhancement and does not show any color-zoning. It is one of the largest faceted magnificent Padparadscha sapphires ever tested.*



*Fig. 8: The picture shows a resting point in the middle of the forest about 5 miles from the mine, equipped with a small field kitchen and the local river as drinking source and bathroom. Photo shows Peretti (in red shirt) and the porters carrying the equipment.*

We crossed two rivers and twice accepted our guide's offer to carry us across, sparing our trousers and shoes from becoming soaked. We were happy with our porters' offer. They were really onboard with our team after we shared provisions with them, and showed their respect by carrying our heavy equipment.

## 15:30 THE ENTRANCE TO THE MINE IS DISCOVERED IN THE JUNGLE

<http://www.gemresearch.ch/video/Didy2.htm>

On the next to last elevation to the mine, we saw the first signs of deserted mining spots with unearthed boulders and holes adjacent to little ponds used for washing.

The weak stream was definitely not in its natural formation, but this was not worrisome. Tropical rain would soon restore the stream's natural flow. The receding flora would soon flourish. Little hills of washed rock were piled up everywhere with dark round boulders to the size of sand. Obviously a small alluvial riverbed was mined.

Bordered by steep hills, it rapidly became depleted, so miners moved on to easier pickings. The abandoned improvised huts showed that this was not just an exploration site, but had active mining for some time.

The trail narrowed and split into little trails overgrown with roots from the surrounding trees. They were everywhere in the rainforest but were visible here as thousands of miners passed over the surface.

## 16:00 AN IMPORTANT GEMOLOGICAL DISCOVERY

The entry of the mine was a muddle of tents and makeshift



Fig. 9

Fig. 10

*Fig. 9: The mining scene in the upper part of the valley with tents housing six to eight people each, re-supply shops (middle right side), water reservoirs for washing mud, mining sites under the trees and debris dumping places. Damage to nature has been minimal compared to wood-logging activities in the same forest. (S 18 20.31 E 48 33.83, 3486 ft)*

*Fig. 10: May 17, 2012: The authors Peretti and Hahn found in the middle of the action, two days before the mine was shut down by government authorities and a few months before big investors took over the operation. At this point of the expedition, the authors were agressed. Photo by Eugene (guide).*

huts on the slopes with countless holes and ditches in the valley. Blue improvised tents hosted up to eight people. We carefully collected this information, to later calculate the number of miners in the area when using aerial surveillance data. We were asked repeatedly, "What are you doing here? Who are you? Were you in the helicopter?" The ones that did inquire about this were distinguished in their dress; not muddy, with shoes, sunglasses and holding torches to inspect gemstones. They wanted to know if we were the competition who would threaten their profit margin.

Many organized miners deliver to agents who provide them with small credits either in cash, tools or food. These agents do not want intruders making counter offers to miners.

Larger stones are routinely brought to the next centers looking for multiple offers and sold to the highest bidder. Obtaining or observing samples directly from the mine is vital, since it is 100 percent proof of its origin. We were able to inspect some rough in the mine and establish absolute proof of the rough's unique crystal habit.

**16:10** Ten minutes into the mine we were still at the entry. The valley widened farther in, where the stream originated. The mine entry had an internal river joining the main stream. The farther we walked, the more miners and housing we saw. We estimated that about 30 percent of those around the mine were actually digging, the rest idling by. Some were women in charge of food and necessities, others were dealers socializing.



*Fig. 11: The filming platform from where high-resolution DVD shots were taken for a documentary that was shown at a GRS seminar during the September Hong Kong Jewellery & Gem Fair.*

## THE FILMING PLATFORM AT THE MINE

We reached a platform with clusters of mining and washing pits adjacent (Fig. 9, 10, 11 and 12). Each cluster contained three to four people displacing mud from small holes with one person disposing the soil by basket right next to their washing place. We were moving on the slope, as the valley was now impenetrable without disturbing the claims and getting knee-high in mud. We planned to make this expedition more downstream but a security breach required a change. At this point, we were consumed by the mining activity having reached a critical stage in our adventure.

It was like the California gold rush that prospectors encountered a century ago. This time, it was for the largest sapphires and rubies ever unearthed (Fig. 14 and 16).

## THE ACTOR AT THE MINE

We found ‘actors’ here who demanded that their pictures be taken. One such show-off swung a thick wooden stick, shouting in Malagasy at miners on the other side, as if he were the King of the Mines. Some people, probably neighbors from Didy, approached. Suddenly, everyone was looking in one direction as shouting escalated. We saw no carbonate rocks on this visit. It was too risky getting closer to pick up samples. We did this later at an abandoned mining spot.

## THE AGITATOR AND THE ATTACK AT THE FILMING STATION

A highly intoxicated miner approached Hahn, chattering nonsensically in French. He was trying to explain that Malagasy people were poor, expecting a handout and calling us American journalists. The drunk persisted, he was dissatisfied with the attention received. He slapped away Peretti’s video camera. Eugene intervened. This drunk had converted his

small liquor bottle into a weapon with Eugene and the miner facing off in Malagasy. A crowd gathered round, and we did not expect them to take our side. Our own porters were frozen in fear, watching helplessly. Eugene commanded the drunken miner to back away, warning him about consequences. He was stunned by the harsh presence of our bodyguard, but resumed his threats. The drunk began shouting across the mining site to the other slope saying, “Americans,” and agitating them to incite riot by falsifying our intentions and mobilizing them to his side. We had to leave the site now. People were still not fully convinced that we were not the American journalists threatening their mining efforts. Our original plan to camp close to the mine was no longer realistic. Getting as far away as possible from the site became our objective. Eugene looked at us with his typical smile; we smiled too, simulating confidence. The three porters followed silently as they had the entire trip. They did their job well, but our real safety line proved to be Eugene’s bravado. Fortunately, Eugene’s head-cam captured some of the most interesting footage.

## THE SAPPHIRE ROUGH AT THE MINE, A REVELATION

While exiting, our “King of the Mine” reappeared proudly showing a sapphire rough weighing approximately 10 carats (see cover photo). It lacked fine color and was worth no more than US\$200. What was very interesting was that the crystal exhibited no growth phases nor showed habit. He had broken his posturing to the others and his air of dominance may mean that a US\$200-stone actually was a big deal. We could not imagine the outcome had we shown him money and made an offer on the stone. Hahn had kept him on our side by letting him feel admired for his low-value sapphire.

On return, we noticed the pervasive blue tents, with some sitting atop deep pits. An entire village of over 50 tents



*Fig. 12: Miners are digging under the trees to reach a secondary alluvial mining deposit with boulders of gneiss, amphibolite, gabbro and quartzite.*





*Fig. 13: A 40-carat GRS-type "Royal Blue" rough sapphire from Didy (Madagascar) that can be cut to a 10- to 20-carat gemstone. Estimated wholesale value exceeds US\$100,000. Note that this is not a crystal fragment but the sapphire's original shape without crystal terminations as grown in the mother rock.*

camped under the trees with improvised shops and gambling platforms with six to eight people inside a single tent. Some huts were double-layered with a professional tent inside covered by a larger one, as a shield against the heavy rain. Some tents covered a mining pit protecting a deep cylindrical hole into the ground.

## GEOLOGICAL FIELD WORK AT THE ABANDONED MINE 17:00

(<http://www.gemresearch.ch/video/Didy3.htm>)

We were determined to walk until dark by using flashlights for another hour and perhaps throughout the entire night. Possibly some miners might be organizing an ambush to rob us along the way back, so moving fast was our best option.

**17:20** We reached the deserted mining place; our last chance to examine and collect rock samples. The porters and Eugene exchanged views on what had just transpired. Finally, Peretti could commence his fieldwork (Fig. 20). With a small



*Fig. 14: At the washing place, we encounter a woman washing, probably from Didy. Her child should be at school. He is most probably searching for platinum and not gold but may not be aware of it (Platinum occurrence See Fig. 17).*



*Fig. 15: Miners digging deeper into the alluvial bed to reach the gem-bearing layers. These layers are carried away with baskets to the washing place.*

hammer he began examining rock samples from the alluvial riverbed. Soon, different types of rocks were identified, like a mica-gneiss, amphibolites, gabbros and quartz boulders. He knew that sapphire often forms in geological systems that produce radioactive minerals, like thorianite-uraninite, zircon or ekanite, which can also be radioactive. So a Geiger counter was brought along. A very slow and systematic scan of smaller pebbles in the waste pile of the mine revealed very highly radioactive minerals after an area of only 40cm<sup>2</sup> by 40cm<sup>2</sup> was searched. The scale measured out-of-limit and its beeping sound attracted the rest of the crew. A large crystal was retrieved for later lab analysis. Hahn and Eugene joined the search attentive to the Geiger counter beeps becoming more intense the closer they got to a specimen. The measurable radioactivity radius with our device was only of 15cm diameter distance (B- and minor Y-rays). It took only 2 minutes to find another sample. 5kg of rock samples were packed and brought back to the laboratory. (Fig. 19)



*Fig. 16: Two strong Malagasy men washing a heavy load of soil that exposes large pebbles from the alluvial bed mostly composed of gneiss, amphibolites and gabbros, but no carbonates.*

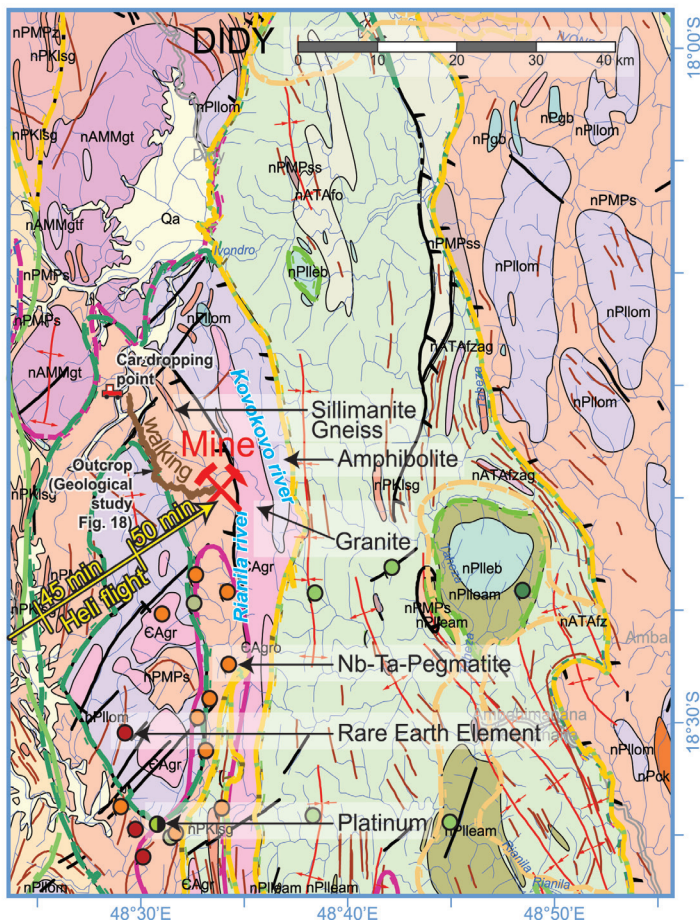


Fig. 17: A map showing the "Geology Dreamland" for the Didy (Madagascar) mine. The mine is situated in the metamorphic rock suite of gneiss, amphibolite, quartzite, intercalated sillimanite-gneiss (complex of Mananpotsy), migmatites garnet and biotite-bearing ortho-amphibolite. The gem-bearing zone is mirrored in the West (approx. 48.50E) with a large intermediate zone of gneiss and amphibolite of the Beforona group and even large bodies of gabbro are found (48.45E and 18.37S). The main difference in the rocks at the mine itself is the presence of Nb-Ta mineralization. As the map shows, this indicates the presence of pegmatite. The Ambalavao rock suite surrounds the mining area and contains quite different rock types including anatectic granites and migmatites. They are partially melted rocks typical for a lower high-metamorphic continental crust. The sillimanite gneisses of Manatopsy corroborate the high grade of metamorphism of this area (high-temperature). The rock types that were predicted by the map (amphibolite, gneiss and quartz) were indeed found in the mining area (Fig.19). Signs for hydrothermal activity were also discovered (most probably in connection with an intrusion) by abundant Fe-Th-Pb-Bi-Zr-Ta-U-Y-Nb-oxide mineral occurrences (Fig. 20) and inclusions (Fig. 26A). Note: the expedition trail in the map and the location of studied outcrop (Fig. 18). The possible scenario of sapphire and ruby formation is different to that in Adranondambo (Madagascar) and Winza (Tanzania) (See Lit. 1, 4) and may be related to fluids and/or melts deriving from plutonites and the metamorphism of Si-under saturated and Al-rich rocks at high metamorphic degrees. Because of the large-scale mapping (1 to 500,000), further small-scale geological studies are necessary for further clarification. The Mine location was added from our GPS data collected, and river systems potentially containing gems are indicated

with names. Legend selectively edited and translated into English from French. Map cropped from Carte Métallogénique et de Prédiction des Gisements, Métaux de Base et Métaux Précieux, Feuille No 6-Toamasina (See Lit. 3).

Legend	
<p><b>Sedimentary and Volcanic Rocks (and metamorphic equivalents)</b></p> <p>Qa Non-specified alluvial rocks</p> <p><b>Betsimisarakana Zone</b></p> <p><b>Mananpotsy Complex</b></p> <p>nPMPs Formation of <i>Sakanila</i> Biotite-Gneiss ± hornblende and amphibolite with quartzite unites/ quartzite lenses, graphite lenses ± sillimanite ± garnet rocks and some calcisilicate marbles Gneiss à sillimanite</p> <p><b>Antananarivo Zone</b></p> <p><b>Mananpotsy Complex</b></p> <p>nPMPz Ambatondrazaka Formation Biotite-Gneiss (± sillimanite ± graphite) with lenses of quartzite and amphibolite</p> <p>Cu</p> <p>Ni, lateritic nickel, nickel sulfide non-specified</p> <p>Be, Beryl-bearing pegmatite</p>	<p><b>Plutonic rocks (and metamorphic equivalents)</b></p> <p><b>Tsaratanana Complex</b></p> <p><b>Beforona Group</b></p> <p>nATAfo Migmatic plagioclase gneiss with biotite ± hornblende and granitogneiss with amphibolite lenses and porphyroblastic gneiss</p> <p>nATAfz Mafic biotite gneiss mafique, banded and locally sheared, with quartzite, amphibole and pyroxene, metagabbro and meta-ultramafite</p> <p>nATAfag Amphibole-gneiss</p> <p>Cr, deposit type not specified</p> <p>Fe, deposit type not specified</p> <p>Ni, deposit type not specified</p> <p>EGP, Alluvial</p> <p>REE, Rare earth element deposit type not specified</p> <p>Sn, deposit type not specified</p> <p>Nb-Ta, columbite-tantalite bearing non-specified pegmatite</p> <p><b>Antananarivo Zone</b></p> <p><b>Ambalavao Series</b></p> <p>€Agro Anatectic granite, idiomorphic K-felspar Facies</p> <p>€Agr Anatectic granite/migmatized, not differentiated</p> <p><b>Kiangara Series</b></p> <p>nPKlsg Alkali granite and syenite gneiss, polyphase stratified, coarse-grained and medium differentiated (biotite syenogranite, alkaline-leucogranite and quartz-bearing syenite).</p> <p><b>Imorona-Itsindro Series</b></p> <p>nPock Granite charnockitic granites or charnockites (not assigned)</p> <p>nPllc Gabbro</p> <p>nPllcam Gabbro Othoamphibolite (not assigned)</p> <p><b>Betsimisarakana Zone</b></p> <p><b>Imorona-Itsindro Series</b></p> <p>nPllom Migmatic hornblende ± biotite garnet-orthoamphibolite</p> <p><b>Betsiboka Series</b></p> <p>nAMMgt Hornblende-tonalite gneiss with ± clinopyroxene and amphibolite boudins ± garnet-bearing and pyroxene metadiorite; local charnockitisation</p> <p>nAMMgtf Mafic granofels/mafic rocks with gabbro-like composition</p>

**19:00** Hahn assisted by Eugene quickly set up camp with a professional 2-layer mountain tent and high-tech mosquito nets, and cleared rocks and sticks to level the ground. The torches attracted mosquitoes and flying insects. Humidity emanating from trees creates its own ecosystem in rainforests. The cold nights make rain inevitable. The porters took out their equipment and built a camp with a small sheet of plastic connected between trees offering some protection against the rain. That night, they placed sheets above the mosquito nets but it covered only about 60 percent of the area.

## Friday, May 18, 2012

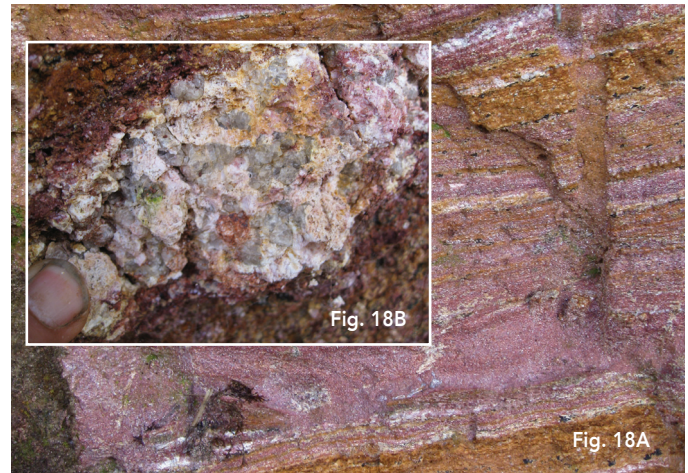
**EARLY RISER** Around midnight, a downpour started and the schedule needed to change. We decided to be up by 4am. The rain would have made the muddy trail hazardous. Peretti contracted some radiation exposure due to mistakenly using his backpack as a pillow containing the radioactive sample. Thankfully, no contamination occurred since the samples were sealed.

**6am** Like the flick of a switch, the darkness was replaced by light. It was an amazing event. The misty fog from last night's rain hovered over the hills. Majestic trees of stunning beauty dominated the scenery in this natural wonderland in Madagascar. It was an amazing sight. The area overlooked the place where the largest rubies and sapphires in the world were found – a paradise of exotic fauna and flora accompanied by calls of lemurs and rare birds.

## GEOLOGICAL FIELD STUDY OF THE ROCK FORMATIONS

(<http://www.gemresearch.ch/video/Didy3.htm>)

Stunned by the wildly diverse and colorful rock formations (Fig. 18A/B) Peretti took dip and angles of gneiss formations and gathered rock samples. Several places on the trail bore signs of small mining activities, signaling that the miners identified this as mother-rock bearing sapphire or ruby. The rock formations were complex layered rocks with different chemistry; with some layers containing amphibole or pyroxene pockets but they were deeply weathered with no fresh specimens available. Interesting boudinage was seen in the rocks' layers. These lenses showed an increase of grain size, and promising to the formation of larger sapphires. The exact position of these rocks was recorded on the integrated handheld GPS, and the integrated GPS in the video camera producing valuable footage.



*Fig. 18A: An outcrop several miles away from the mine on the hillside (marked in Fig. 5) exposes an extremely tectonized and stretched rock suite with a very inhomogeneous chemical composition shown by its weathered colors. Apart from a few minerals such as probably pyroxene or amphibole (see finger pointing), only quartz layers have survived the deep weathering.*

*Fig. 18B: The inserted picture shows a strong boudinage of the rocks during tectonics in certain areas with an increase in grain size. Such local occurrence in the rocks would be beneficial and necessary if the rubies and sapphires are formed by metamorphism. Miners did attempt mining at this spot and it seems their experience made them conclude it was not worth the effort.*



*Fig. 19: Amphibolites and gneiss rocks that were found in the riverbeds of the mines are shown. The rock-type was predicted by the geological mapping (Fig.17) and is a potential good culprit in the general scenario of sapphire and ruby formation. It is only part of the alluvial layer; a primary rock formation containing the gems was not exposed. (GRS Rock Collection.)*

## RE-STOCKING THE MINES

**8am** Increasingly, miners and villagers passed us on their way to the mine (Fig. 6). While we were walking out, they were going in with new supplies. They used sticks and metal poles to suspend rice sacks filled with rice, cooking oil, medicine and cigarettes. We could also estimate the population at the mine by calculating the food supplies being brought in. We interviewed the porters on the contents of their load. Then we created a formula based on 5,000 calories of daily consumption per person. By counting the number of porters and inquiring about their cargo, we estimated that approximately 450 people transported 2 tons of consumables including a live cow to the mine daily. There were likely 5,000 to 10,000 miners at the mine.

The average load was between 20kg to 40kg per porter. We were later informed that a pack of rice sells for US\$30 at the mine, three times the regular price. People at the mine were not only chasing their dreams, they were making substantial personal investments. Thinking back, we estimated only about 30 people leaving the mine the day before. Only dealers questioned us when we left. A group of 20 to 30 influx miners told our porters they heard the day before that the mine is going to be closed by foreigners, a disturbing forecast. We assured them that we were not interested in shutting them down. Hahn explained in French that like them, our business depends on mining activity.

## AT THE CAPITAL ANTANANARIVO

**10:20** Arriving in Antananarivo after a one-hour helicopter flight (Fig. 3), Hahn asked the pilot to hold up the flight log “la fiche de vol” so he could take a picture, otherwise we would have never discovered the rogue helicopter trip. Peretti paid US\$2,000 surcharge for the extra kilometers flown, most of which were non-authorized.

**AVOIDING AN AMBUSH** A driver drove us out of the heliport compound and stopped after the window suddenly exploded from the middle out. The right rear window had burst into tiny glass bits just 20cm from Peretti’s head. Hahn ordered the driver to leave immediately, thinking they were being ambushed with some type of projectile. The heliport was alerted and the police apprehended a disturbed woman within 30 minutes caught throwing stones. We thought this incident was resolved way too fast and was most likely a fabrication. The person or the object should have been noticed, so it had to be fired from far outside our line of vision, and was never recovered. Peretti could not move for the rest of the ride to the hotel because of the glass shards covering his neck and arms.

Our phones kept on ringing. Someone wanted us to test a large stone while another wanted money. With no stones to be

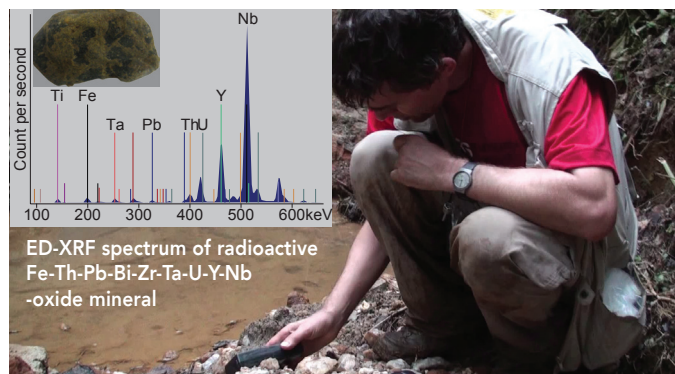


Fig. 20: Peretti examines the leftover gravel of a mining site with a Geiger counter and discovers highly radioactive minerals (Fe-Th-Pb-Bi-Zr-Ta-U-Y-Nb-oxide mineral).



Fig. 21: A set of eight highly valuable faceted rubies ranging from 7 to more than 14 carats in size in the hand of one of the authors (AP) exceeding an estimated market value of US\$10 million. Two of the stones over 10 carats were classified as reminiscent to GRS-type “Pigeon’s Blood” color category. The Didy (Madagascar) rubies made an overnight appearance to become some of the world’s largest rubies unearthed so far, competing in beauty and rarity with the finest Burmese rubies.



Fig. 22: A closer look of an over 7-carat ruby from Didy (Madagascar) demonstrating complete absence of eye-visible inclusions. These rubies from Didy lack silk nests that would potentially disturb the clarity of a stone by producing eye visible whitish reflections. The rubies are so clean that synthetics are easily smuggled into the lots at the mines. (Photo: W. Bieri. © GRS.)

exported except reference specimens (Fig. 26A-D), we boarded our flight to Bangkok. Passing the boarding checkpoint, Hahn was singled out by customs for a random bag search along with four individuals who appeared to be from mainland China. Hahn told the customs officers that it was not necessary to search and make a mess out of his stuff. Miraculously, it worked.

**THE AFTERMATH** Two days later, mining police moved into Ambatondrazaka and the non Malagasy dealers closed their buying operations, temporarily retreating to the capital for a few days. With the mining area also raided, the miners cleared out. The miners and dealers have gone back by now or relocated to slightly different areas in the forest.

Some passengers traveling with our helicopter were investigated for an unauthorized helicopter trip, and petitioned Peretti for a copy of his authorization. Peretti sent the documents to resolve the matter, but he was not aware that an investigation was ongoing regarding the dissemination of business cards and illegal solicitation in an unauthorized mining site. The man whose name was on the card was imprisoned and had to put up considerable bail. The matter as to how GRS would be compensated for the air hijacking during the expedition is still unresolved.

**WORLD RECORD RUBY PRICE** At the June Hong Kong Jewellery & Gem Fair, news reached us that a dealer sold a 7-carat vivid red ruby (Didy) for US\$1million (Fig. 14). These rubies were true record-breaking treasures of nature. GRS was the only company in the trade that witnessed the activities in this mine firsthand.

### GRS RELEASES THE NEWS

(<http://www.gemresearch.ch/video/Didy6.htm>)

**October 22** GRS hosted a seminar, "New World Record Pigeon's Blood Rubies Discovered," during the September Hong Kong Jewellery & Gem Fair. The new findings were presented at the said event. (see [www.jewellerynewsasia.com](http://www.jewellerynewsasia.com) - keyword: GRS)

### INVESTORS TAKE MINING RIGHTS

**October 30** The following information was received from the gemstone market: A major investor (GF) has taken the mining rights in the upper part of the valley and a private investment group involving non-Malagasy nationals has secured the mining rights in the lower part of the valley. Both are hiring locals from Didy for the work at the mine.

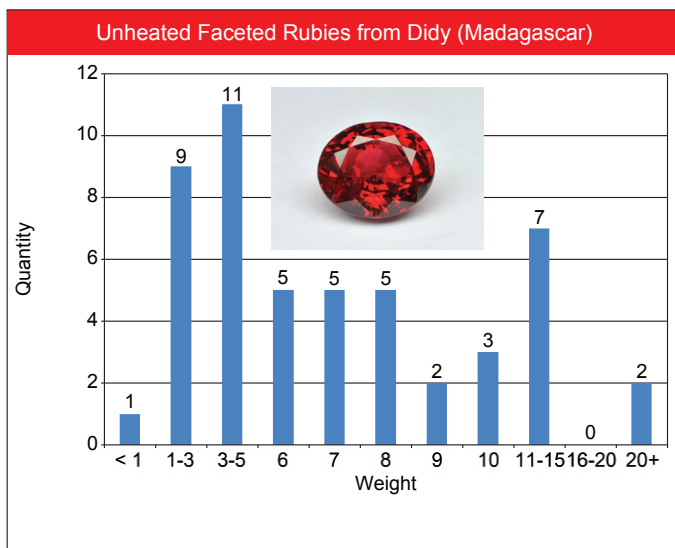
The investment group currently has at least two agents in the forest supervising the operation. Additional wild mining must be taking place since a 128-carat rough sapphire had been submitted to GRS from outside these two mining operations. Submissions of stones originating from Didy to the lab have also resumed.



*Fig. 23: A set of sapphires from Didy (Madagascar) ranging from 5 to over 10 carats with the typical GRS-type "Royal Blue" colors normally found solely in sapphires from Sri Lanka, Burma and Ilakaka. (Madagascar). (Photo: W. Bieri. © GRS.)*



*Fig. 24: Peretti works with a portable microscope to search through lots of rubies and sapphires of dealers in Ambatondrazaka. The presence of ilmenite, zircon clusters, blue color zones and absence of silk make these rubies very easily distinguishable through microscopical examination from all other ruby localities, even from the counterparts found in Winza (Tanzania). The same is true for the sapphires that contain large negative crystals accompanied by secondary fluid feathers, isolated zircon crystals, black ilmenite inclusions, oriented pargasite needles and the general absence of silk (Lit. 2).*



**Fig. 25: Statistics of 25 rubies from Didy (Madagascar) tested by GRS just three months after the rubies were discovered. It shows that after only a short period of time two magnificent rubies over 20 carats appeared. Such large rubies are usually the positive by-products from decades of mining in large areas such as Mogok (Burma, Myanmar). Statistics by GRS.**

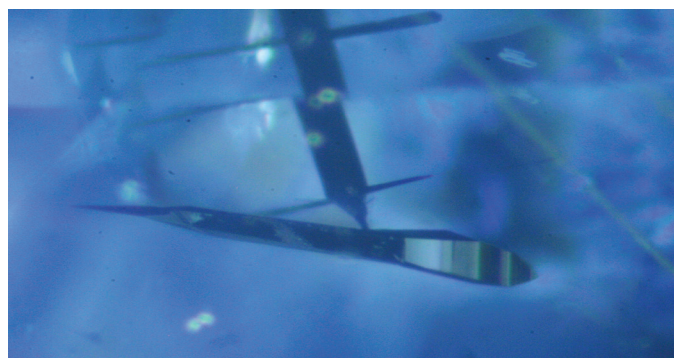
Lit. 1 Adolf Peretti, Francesca Peretti, Anong Kanpraphai, Willy Bieri, Kathrin Hametner and Detlef Günther. Winza Rubies Identified. Contributions to Gemology (2008), 7-97 pp.

Lit. 2 Adolf Peretti, Willy Bieri, Kathrin Hametner, Lawrence Hahn and Detlef Günther (2013). World-record rubies and sapphires from Didy (Madagascar) and the new sapphire mines from Kataragama (Sri Lanka). Expedition Report, Geology and Gemology. Contributions to Gemology, No. 12, in print.

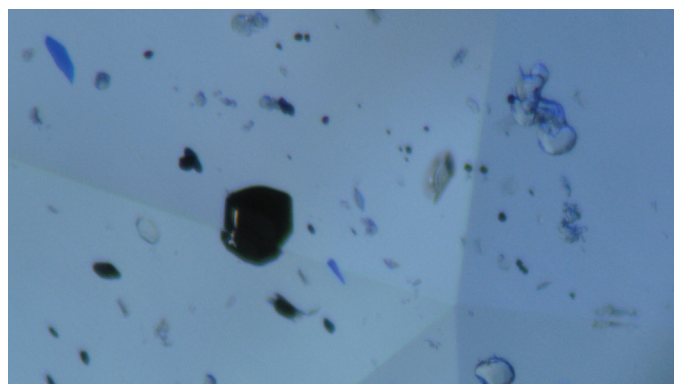
Lit. 3 Carte Métallogénique et de Prédiction des Gisements, Métaux de Base et Métaux Précieux, Feuille No 6-Toamasina (2008) (J. Ramarolahy, D. Rakotomanana, B. Moine, E. Ortega, L. Chevallier, F. Hartzler, G. S. de Kock, S. W. Strauss et, A. F. Randriamanantenasoa, J. Naden, L. Noakes, Editée par: British Geological Survey Keyworth, Nottingham, UK) MINISTÈRE DE L'ÉNERGIE ET DES MINES Projet de Gouvernance des Ressources Minérales (PGRM).

Lit. 4 Edward Gübelin and Adolf Peretti (1997): Sapphires from Adranondambo mine in SE Madagascar: evidence for metasomatic skarn formation. *Journal of Gemmology*, Vol. 25, No. 7., pp. 453 - 470.

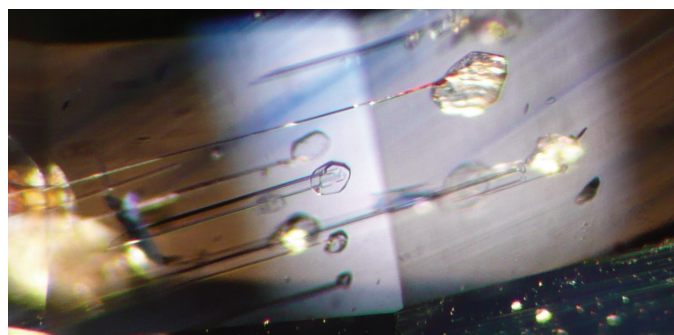
Lit. 5 Jewellery News Asia – Show Daily, 24th Sept. 2012, page 10.



**Fig. 26A: Large Mn-Y-Nb-minerals were found as inclusions in Didy sapphires in the shape of ice-picks. This corroborates the theory that the sapphires are formed in connection with Nb-Ta-pegmatites.**



**Fig. 26B: Mica, ilmenite and zircon inclusions are found in a Didy sapphire of over 5 carats. (GRS Collection.) These minerals are common in amphibolite-gneiss rock suites found at the mine. Ilmenite was confirmed by GRS using SEM-EDS analysis in July 2012. (M. Meier, SEM-laboratory, Geoscience, University Fribourg, Switzerland)**



**Fig. 26C: Pargasite needles are grown from fluid inclusion voids and have penetrated the entire sapphire in orientation. This is the first time one of the authors (AP) has seen such a phenomena in a sapphire and it shows that the sapphire was grown in a dramatic hydrothermal event. Color zoning is also present in this sapphire and the zoning discontinues irregularly. No whitish milky zones are present such as in other sapphires from Madagascar.**

GRS would like to thank the Y. Group for making us discover Didy while providing infrastructure and hospitality on the ground; Tom Cushman for the strategic planning of governmental and local passage permissions, and organizing transportation and data; the Government of Madagascar and the Mayor of Didy for passage permission and providing local support; Gem Paradise and friends for sourcing opportunities; all local miners; Assist Aviation; Ghambi; Diana Jarrett; and most of all, our porters who did an amazing job together with Eugene who might just have saved our lives. And last but not least, the amazing GRS team for holding the fortress at the peak of the laboratory workload.



*Fig. 26D: A folded feather within a faceted ruby from Didy (Madagascar). Such features are normally expected in sapphires and not in rubies. (Inclusion Photos: W.Bieri & A.Peretti. © GRS.)*

# GRS



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# 马达加斯加Didy矿区破天荒发现红·蓝宝石： 源产地勘查

作者：Adolf Peretti博士 (FGA FGG) 及Lawrence Hahn (GG)  
GRS實驗室 (<http://www.gemresearch.ch/video/Didy5.htm>)

于2012年5月，一位客户专程从马达加斯加飞往曼谷的GRS实验室，送来两大颗优质红宝原石(图1A)，请实验室进行测试。

客户表示，马达加斯加传闻，指当地的晶石其实是人工合成，所以他忧心忡忡，必需先确认晶石为天然真实的，他的集团方会进一步投资。

实验室利用能量发散X-光荧光光谱仪(ED-XRF)、傅立叶转换红外光谱仪(FTIR)、紫外-可见光谱仪(UV-VIS)、拉曼光谱(Raman)及显微镜测试样本，发现该大颗晶石确实是天然且未经加热处理。为肯定这些晶石是来自客户所疑虑的矿区，两位作者开展冒险旅程，亲身前往晶石的来源地，勘查矿区实况，以获得第一手资料。他们拍摄当地采石热的情况，并从矿



图1A及B.来自马达加斯加Didy超过60卡的宝石级原石，乃琢磨成超过26卡的瑰丽红宝石(图右)。这些瑰丽红宝石的售价创下世界记录，更令人趋之若鹜、触发抢购潮。除非另有注明，否则所有图片均由作者Peretti及Hahn拍摄，而版权则由GRS所有。(<http://www.gemresearch.ch/video/Didy4.htm>)

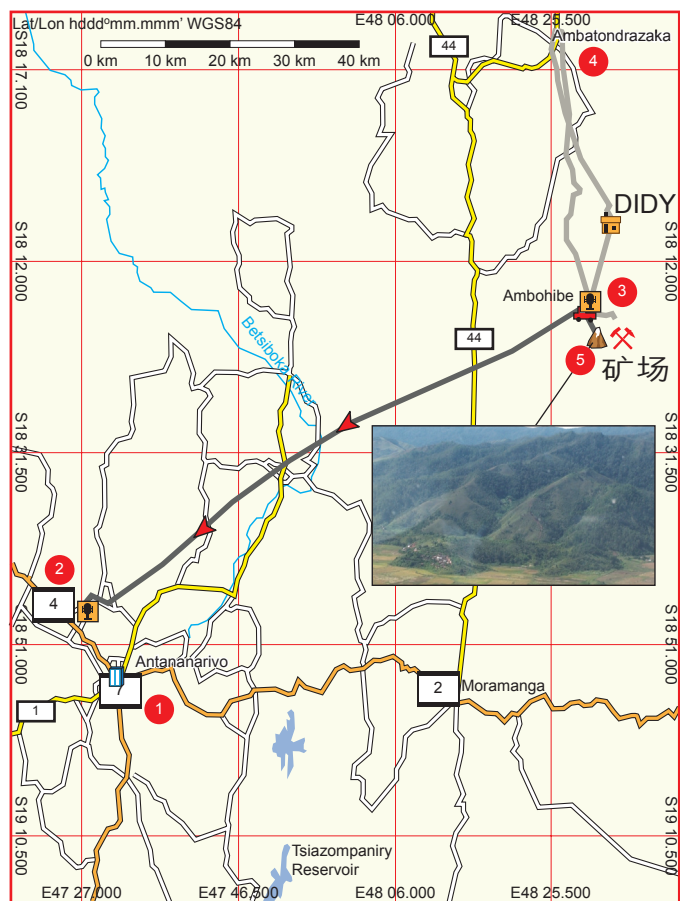


图2.我们自家的GPS所记录直升机前往矿场的一节详细飞行地图；3-4.天气良好，我们乘坐航班从Ambohibe前往Ambatondrazaka，机上计算机故障，所以这段航程由Peretti领航。(图5) 4-3天气恶劣，并无使用GPS，航机随着地形飞行，前往Ambohibe；3-2途经雨林回程到首都(1是首都Antananarivo)。





图3从Didy矿场考察归来后，作者Peretti（左）及Hahn（右）拍下照片，留住令人难忘的一刻。回程时的考察物品重量超过150公斤，包括便携式宝石实验仪器及露营装备。饱历16.5小时艰辛丛林步程往返矿场后，两名作者赤着无比酸软的双脚；而爬山鞋亦沾满泥泞。（照片：Cushman ©GRS）

区采集岩石及矿物样本以作比较，藉此了解地底下钢玉矿床形成位置的地质状况。

他们也要获取重要的红蓝宝石标本以作进一步研究(图7A及封面)。在马达加斯加每次进行实地考察，都涉及安全风险，物资运输会遭遇种种困难，更经常要有技巧地与当地居民及政府谈判。就单单前往当地，首先要克服连串挑战。Peretti忆述：「首先坐12小时汽车到达Ambatondrazaka (Amba)，接着，若然天气良好，驾车3至5小时，便可到Didy；但最后还需步行至少一日，方抵达目的地。然而，在这个未知国度，不能保证能够成功通过看似受保护，但又阻隔重重的雨林，到达首都东北部。」因此，Peretti决定乘搭飞机较佳，并获得一位当地前珠宝商帮助，安排一辆直升机由Antananarivo出发，飞越国家公园上空，再确定矿区位置，及标绘明确的全球定位系统(GPS)坐标。然后，他们会决定最近的降落地点，再前往Didy，以向当地政府办理通关批文，继而选择合适交通工具，向目的地进发。航空公司在Amba设置加油站，备有400公升汽油储量，而从他们离开Antananarivo起，至飞往Amba的12小时行程中，均有直升机机员随

行协助(图2)。

Peretti考察日记中摘录的内容揭示了实地考察期间所发生引人入胜的故事。

## 2012年5月14日星期一

不久前，GRS实验室接到消息，表示政府已封锁了一个有约30,000名矿工的矿区，以防止外来人进入。距离最近的村庄步程需3小时，当地人或政府当局设置的路障，加上滂沱大雨及恶劣路况，使得我们举步维艰，以致需要几



图4A



图4B

图4A.距离矿场南面10公里的花岗岩石形成一个山脉（较能抵受风化）。（见图17的地质学）。

图4B. GRS飞越Zahamena-Ankeniheny受保护森林时拍下马达加斯加Didy矿场营地的空中照片（插图Peretti于机上GPS计算机故障时负责领航）。

乎15个小时车程，才能从Antananarivo(名为Tanarive首都)抵达最接近矿区的市镇Didy。

## 2012年5月16日星期三

Zahamena-Ankeniheny是推测采矿活动所在的必经之路，虽然未成为国家公园，但已获当局建议纳入保护区域，故特别称为国家公园，划入受保护区域类别内，以防止环境被破坏。

## 飞越新矿山

(<http://www.gemresearch.ch/video/Didy1.htm>)

飞机在雨林覆盖的悬崖峭壁上空越过，壮丽景色令人叹为观止(图4A)。飞行40分钟后，机师

宣布我们已抵达GPS坐标所在位置，地面上聚集了一群人(图4B)。这个蓝宝石区域称为Didy，官方名称是Ambatovolona。

沿着河床在矿区上空盘旋，我们看见矿工们正忙着挖掘与洗选。地面上几乎每个人都停下手上工作，目不转睛地盯着直升机。我们发现第二个面积较小的地方，意味着矿工现正扩大采矿范围，开发不同领域。我们看到百多个蓝色帐篷，究竟这里实际上有多少矿工？这儿看来与我们之前所推断能容纳30,000名矿工的营地并不相像，反而像是待了5,000至10,000名矿工，而且采矿毫无组织，只是一大群人各自以「先到先得」的方式工作。

盘旋几圈过后，我们已拍摄足够的相片及影片，不希望继续打扰矿工，所以Peretti示意机师离开这一区，寻找最近的降落地点。矿区延绵几座小山，在雨林内横跨约5至10公里，但矿区附近似乎并无可以降落的地方。未几，我们发现森林边缘停着多辆汽车，车主很有可能是宝石买家。接着我们发现一座小山，山上有6所房子团绕着陡峭山道而建，乍看像是在山顶上架设要塞的中世纪村庄，我们称之为「鹰之窝(the Eagle's Nest)」，之后得知其实际命名为Ambohibe。

可能降落的最近地点距离鹰之窝旁边矿区8分钟机程。我们看到一块收割完的水稻田，土质已变硬，有几头牛在闲遛。我们尝试在该处降落，并保存GPS坐标以方便回程。于是，我们决定先研究这儿的环境，再前往Didy。

在Didy降落时，我们碰见一大群可爱的孩子和看来友善的当地人，孩子们对当地长辈谦恭顺从。显然，这群孩子是第一次见到直升机。村长解释说，所有身强力壮的男人们都去了森林采矿，把稻田里的繁重工作留给妇女们做，导致今年收成惨淡。我们与当地政府商讨，获得重要批文，才得以参观矿区。

随后我们抵达Ambatondrazaka。在出发前我们联系好一家可靠的机构，在我们到达后给予我们相当多的细小红、蓝宝石，供参考采样。我们利用便携式实验仪器(图24)检测了一些大

颗红、蓝宝石标本，并了解到矿区确实存在，更能出产大颗、未经加热且色彩鲜明的宝石。我们开始尝试设法进入矿区，但日益感到焦虑，我们也许期望过高。「对于认真的地质考察工作，留在矿区单一日的行程根本不足够，另外，矿区会否证实蕴藏量不多，只属昙花一现，而并非藏量丰富，能真正带动采石热潮？」我们得知一个很实用的方法-「买香烟给矿工们」。Peretti回想起，在偏远地区Ilakaka工作的矿工总会问同一个问题「有香烟吗？」，尤其是拍照及录像之时，他们都期待得到「回报」。

### 2012年5月17日，星期四，上午8:00

陷入被俘虏的险境 绕着较低云层盘旋后，我们终于降落地面，当地居民看上去非常冷酷，充满敌意。他们包围了我们，并用四驱车堵住

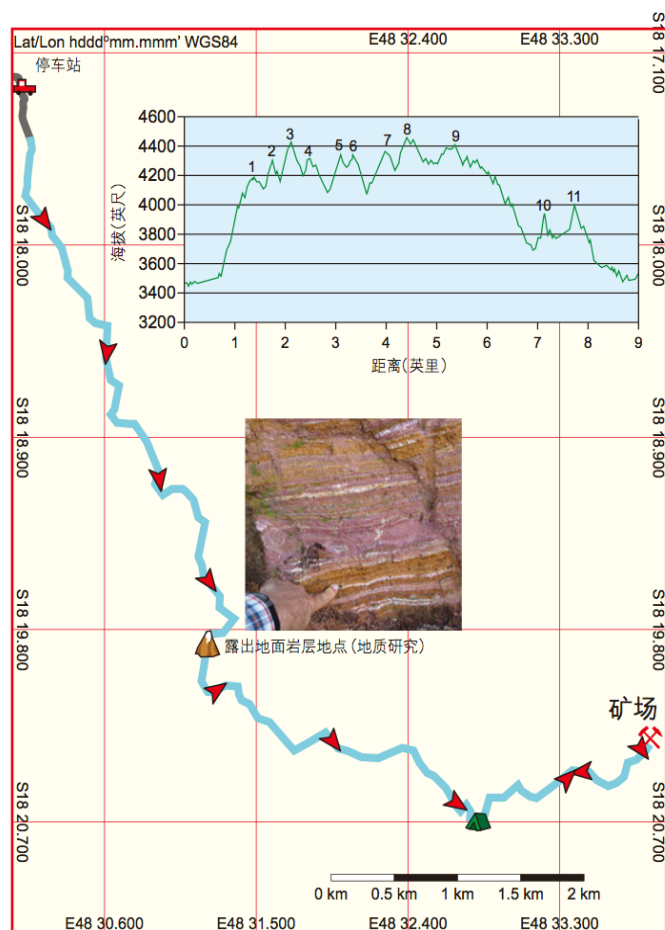


图5. GPS追踪穿越森林前往矿场的行走路线，包括所行进的海拔图。图中显示前往矿场途中首次攀登峭壁及横过约14个小山（峰）。红色箭嘴标示每隔约一小时停下来喝水及进食。地质图中显示路线。（图17）

了我们的出口路线。一位并非马达加斯加国民的商人说，「当地的『首领』索价1,000美元，作为降落权费，另外2,000美元作为通行税费！」无视我们从Didy获取的官方批文。我们连同直升机都被他们团团包围。我们协议不会答应他们的「开价」，经过一轮协商，「开价」降至1,000美元，才打破了僵局。我们从一个我们命名为「车站(Car Drop-off)」(交通工具能到达的最远地点)(图5)的地方开始进发。这一车站聚集了各式各样四轮驱车，车主为一帮当地的宝石买家。当地人纷纷向我们投以敌对且愠怒的目光，直至意识到我们并无恶意，气氛才缓和起来。我们事先安排了司机翌日在这里接送我们，但他却失踪了，再也没有碰见过他。徒步远征 我们在GPS设定矿区及这车站入口的坐标后，开始了长达16个半小时的步行。我们带同一个向导还有4个搬运工人帮忙携带设备，包括帐篷、食物及水，而我们则行携带摄影器材。

起初，我们走得很顺利，以每小时约行进6公里路程。我们满有信心，沿着旁边种满稻米的河谷小溪前进。再往前走，小路变得杂草丛生。我们遇到两个人，他们扛着又大又重的原木(或许是花梨木)，朝鹰之窝的相反方向走去。这些原木看来像是在受保护雨林内的工厂剥皮、成型、备妥、并由人工搬运以作出口的。这些非法伐木工人大概亦是率先发现宝石的。



图6.一名满身淤泥的矿工为矿场补给重量达30-40公斤的米、油、小河鱼及香烟。由于淤泥粘脚，这名矿工的鞋子散失，只好赤脚行走。

向导Eugene兼任保镖。我们雇用的员工需要补充能量，于是停在附近一间小屋吃一碗鱼饭，好好装备自己。此处乃受保护雨林的入口，已有另一群买家聚集，他们似乎未能适应艰苦的徒步旅程，正在一间临时搭建的小屋内收听收音机节目放松休息。我们将要捱过漫长的登山旅程，沿着每段200米的路径不断上山下山。Eugene殿后，确保无人迷路或受伤。山路崎岖难行，但总体是向高处进发(图5—海拔图)。

## 未经批准的宣传举动直升机航班，上午11:34，Ambohibe

回家后，我们细阅机师的飞行日志，发现在离开降落地点后2小时，直升机机组人员曾让一位陌生人登机。

直升飞机从Ambohibe起飞，按指示返回Amba，但这次却未经批准接载了一名盲人乘客。机师记录了每一位乘客的姓氏与名字，唯独盲人乘客只以其姓氏「A」识别。我们假定机师受贿了。据情报，盲人乘客正是之前索求通行税费的「首领」。整个旅途结束之后，机师承认在未经出资人许可下，窜改乘客名单及路线指示。这一组特立独行的人，在矿区上空飞过时，一边拍摄相片一边从直升机上抛下商业名片。这个鲁莽的行动不幸地令GRS未能独家记录当地情况，每个在矿场的商人都提高警觉，害怕外国人入侵他们的地盘。那些商业名片意味着矿场即将公诸于世，令危机增加。机组人员是否为了商业利益，就能轻易被利用，做出不道德的行为？他们是否被A胁迫，所以一概保密？抑或为了策略结盟而帮「A」一把？极有可能的是，其它非马达加斯加人预先计划好这出宣传闹剧，藉以加强他们的购买力。

直升机来来回回飞了好几遍，Peretti和Hahn却毫不知情。到底他们是否仔细选择路线，以避免被发现？

## 在通往矿场的丛林小径上 午饭时间，中午

旅途中，搬运工人和向导没有携带粮食，只带了一瓶水共享，途经河流时补充食水，我们最终需要与他们分享三分之二的粮食(图8)。

与白种人截然不同的，他们在旅程中几乎不流汗。虽然搬运重物，但他们在这里成长，早已习惯当地炎热的天气。

山路土地泥泞，草木丛生，地势越见陡峭；我们的速度减慢，每小时只能走2公里的直线距离。路上遇上二十多位友善途人，都多次问我们是否乘直升机来。我们解释我们是地质学家和游客，并非记者和买家。我们不知道他们所指的是数小时前他们见过的直升机。有些人向我们兜售宝石，但我们决定什么都不买，因为钱财不可露眼。什么都不买其实是很为难，我



图8.这图片展示距离矿场约5英里森林中间的休息点，配备小型野外煮食用具，他们以当地河流当作水源及洗澡的地方。照片展示Peretti（红衣者）与携带设备的搬运工人。

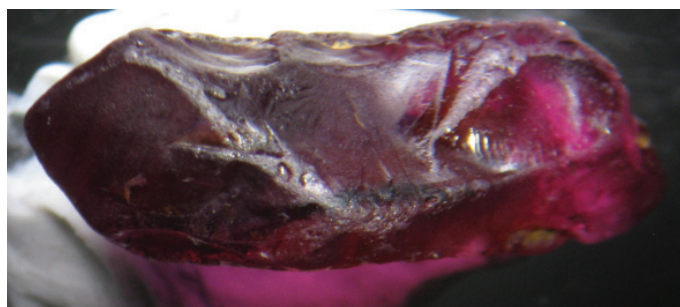


图7A.产自Didy的典型4卡红宝石。这并非碎石，而是完整保存且未经琢磨的原石。红宝石形成时掺杂其它矿物，并留下各类影响价值的痕迹。并无发现任何经河流飘流的迹象（概无圆润的边角和刮痕）。石块上只有与矿物（必须含钛）连接的一边才会出现蓝色带状分布。（Hahn的收藏品）



图7B.左面是85卡未经琢磨的帕德玛(Padparadscha)蓝宝石，非常清澈亮泽，估计价值超过1百万美元。另一颗是价值不菲的经琢磨18卡帕德玛蓝宝石，以正面向上及侧面展示。这颗产自Didy的帕德玛蓝宝石于放大镜下毫无瑕疵，橙色与粉红色完美融合，质量不受高热影响，并无任何带状分布。这是从事测试工作以来遇过最大颗经琢磨的瑰丽帕德玛蓝宝石。

们实在很想从出产地得到相关样本。不过我们其实无权擅买宝石，也不想马达加斯加商人认为我们会抢走他们的生意。有些人开口求售，但本意并非真正售卖宝石，他们实际上是经纪，只是想试探我们是否在寻找宝石。我们强调我们是在私人公司工作的瑞士和德国公民。谣言盛传美国记者将至—当地人明显不欢迎记者。当地矿工和商人对直升机不断到来感到忧虑。

我们过了两条河，并两次接纳向导的建议载我们过河，免得衣履尽湿。我们很满意搬运工人的建议。共享粮食后，他们和我们团队一同上船，而且帮我们搬运重型装备，以示尊重。

### 15:30 在丛林发现通往矿场的入口

<http://www.gemresearch.ch/video/Didy2.htm>

在通往矿场前的最后一块高地附近，我们在用作洗选的小池塘旁边，看到外露的巨石和河口水，这是我们首次发现荒废矿区的痕迹。

细弱的河流显然有异于其原貌，但我们却并不担忧。随着热带雨下降，很快会恢复河流本身的流量。消失了的植物将再次茂盛起来。被冲走的岩石在四周堆积如山，其形状小至沙粒，大至又黑又圆的巨石。很明显，细小的冲积河床曾被开采。河床矿藏毗邻陡峭山坡，已被迅即开采殆尽，矿工于是另觅容易开采的地点。这个临时搭建小屋已废弃，显示此地不只是用作勘探，更曾在一段时间内进行活跃的开采工作。



图9

图10

图9.山谷较高位置的采矿环境，有每个可容纳六至八人的帐篷、补给站（中间右面）、清洗泥泞的储水库、树群下的采矿地盘及瓦砾弃置点。与于同一森林的伐木活动比较，采矿对大自然的损害属轻微。（南纬18 20.31度、东经48 33.83度，3486呎）

图10. 2012年5月17日：于矿场被政府机关关闭前两天，及大型投资者接管营运前数月，两名作者Peretti及Hahn处于备受威胁的局面。考察行动至此，两名作者遭受挑衅。（照片：向导Eugene）。

小径越来越狭窄，并分散为几条树根丛生的狭径。雨林内狭径众多，由于曾有数以千计的矿工路过此地，这几条狭径显而易见。

许多有组织的矿工都由经纪聘用，经纪给予矿工少量信贷，如现金、工具或食物，而这些经纪不希望入侵者再出价招徕矿工。

### 16:00 宝石界一大发现

矿场入口的山坡上布满帐篷和临时搭建小屋，杂乱无章，山谷中有无数的矿洞和沟渠。蓝色的临时帐篷最多可容纳八人。我们小心收集这些资料，好等日后用空中监测数据来计算此地矿工的数目。期间，有些人不断问，「你们在这里做什么？你们是谁？你们曾坐直升机吗？」我们可从发问者的服饰辨认到他们：没有泥泞、穿鞋子、戴墨镜及手持火把去探查宝石。他们想知道我们是否有意分一杯羹，危害他们的收益。

较大颗的宝石通常会转送至邻近中心，寻求更多出价，并售予出价最高的竞投者。从矿场直接取得或观察样本极其重要，原因为这是百分百可靠的来源凭证。我们得以探查矿场内一些原石，肯定地证明其独特的晶体习性。

16:10 我们向着矿场进发，十分钟后仍然身处入口位置。山谷路面越来越广阔，而深处为河流的源头。矿场入口有一条内河连接主河流，再步进山谷，我们发现越来越多矿工和房屋。我们估计实际挖掘范围为矿场周边约30%的土



图11.拍摄高解像DVD记录片所在的平台位置，这段记录片已于9月份香港珠宝首饰展览会上在GRS研讨会中播放。

地，其余尚未开发。这里有些女士负责管理食物和日常用品，其它则是四处交际的商人。

### 矿场的拍摄平台

我们抵达一块平地，附近有多组矿坑，旁边设有洗选处(图9、10、11及12)。每组有三至四人从小洞挖走泥泞，另外一人在洗矿处旁边用篮子筛走污土。现在山谷已关闭，为避免造成骚扰及步入高及膝盖的泥泞当中，我们继续在斜坡上行走。我们原本打算前往更下游的位置考察，但由于安全问题而令计划改变。因此，我们只好花时间在开采活动上，这也是我们历险的关键阶段。

这次旅程好比一个世纪前采矿者经历的加州淘金热。不过，这次是探索历来发掘出最大的红宝石和蓝宝石(图14及16)。

### 矿场的演员

我们在此遇到多位「演员」，要求拍照。其中一人挥动粗木杖，用马达加斯加语呼喝着另一边的矿工，把自己当成矿场之王，亦有一些人走近，他们可能来自Didy邻近地区。突然，呼喝声响起，所有人目光投向相同方向。我们在此行并无发现碳酸盐岩，但走近采集样本实在太危险，所以我们其后在一个废弃矿场内采样。

**在拍摄地点遭遇煽动者及袭击** 一名喝得烂醉的矿工走近Hahn，以法语无意义地嘀咕着。他尝试解释马达加斯加人是如何穷困，并期盼救

济，更称呼我们为美国记者。醉汉继续说着，但他不满现场反应，一手拍开Peretti的摄影机。Eugene插手调停。醉汉把手上的小酒瓶作武器与Eugene对峙，矿工纷纷以马达加斯加语叫嚷。一群人围过来，我们不认为他们会站在我方。我们的搬运工人都噤若寒蝉，只能无助的旁观。Eugene喝令醉酒矿工退开，警告其后果。他起初被我们保镳的威势震慑，但随即故态复萌。醉汉向另一边斜坡的矿场工地大喊：「美国佬！」又诬蔑我们来此的目的，煽动其它矿工群起骚乱，以获得更多支持。我们不得不离开此地。众人都仍然认定我们是美国记者，会威胁他们的采矿生计。我们原定计划靠近矿场扎营，这时看起来不再可行，远离矿场才最安全。Eugene以其一贯微笑看着我们；我们也向他报以微笑，一起佯装并不畏惧。三个搬运工人一如整段路程，静静的跟在我们身后，他们一直以来都努力帮忙。我们能真正全身而退，全赖Eugene虚张声势。幸好Eugene头上的摄影机捕捉到某些最惊险的镜头。

**矿场中蓝宝石原石面世** 我们离开时，「矿场之王」再次出现，风骚的向我们展示一颗重约10卡的蓝宝原石(见封面照片)。它欠缺色泽，价值不高于200美元。有趣的是这晶体并没有显示其生长外形或习性。他放下身段，不再嚣张，到此兜售宝石，可见200美元对他来说可算是大买卖。很难想像如果我们拿钱出来，开价求购时，会是怎样的一个情景。Hahn让他继



图12.矿工正在于树下挖掘，掘到布满片麻岩、角闪岩、辉长岩及石英岩的第二冲积采矿矿床。



图13.一颗来自马达加斯加Didy的40卡GRS类「皇家蓝宝石(Royal Blue)」原石，可切割成一颗10至20卡的宝石。估计批发价超过100,000美元。注意这颗蓝宝石并非水晶碎石，而是在原生岩中形成，完全无水晶尖端的蓝宝石原状。

续站在我们身旁，使他以为我们会因为其平价蓝宝石而对他另眼相看。

回程时，蓝色帐篷随处可见，有些还搭建在深坑之上。全村有超过50个帐篷搭建在树下，更设有临时商店和赌桌，每一个帐篷聚集六至八人。有些小屋以两层搭建，以一个较大帐篷覆盖专用帐篷，以遮挡大雨。有些帐篷盖着矿坑，以防护通往地底的圆柱形深洞。

## 废弃矿场的野外地质考察 17:00

<http://www.gemresearch.ch/video/Didy3.htm>

我们决定以手电筒作照明，步行多一个小时，直至天黑，甚或步行整个夜晚。

有些矿工可能于回程路上埋伏，以抢劫我们，所以速离此处实为上策。

17:20 我们抵达荒废的矿区；这也是我们最后一次机会去检视和收集岩石样本。搬运工人和



图14.于洗选处，我们遇到一位很有可能来自Didy、正在洗选的妇人。她的孩子应该上学但帮忙在侧，他很大可能是在寻找铂金，而非黄金，但他未必能发现铂金的存在。（见图17，发掘铂金）



图15.矿工在冲积床挖掘更深层，达到含有宝石的岩层。矿工挖掘岩层后，以篮子带走岩石，再运到洗选处。

Eugene对于刚才发生的事交换了意见。这时，Peretti终于可以开始野外考察(图20)。他手持小锤，检视冲积河床上的岩石样本，很快就辨认出不同种类的岩石，如云母片麻岩、角闪岩、辉长岩及石英巨砾。他深知蓝宝石通常于出产放射性矿物的地质环境中形成，如方钍石晶质铀矿、锆石或硅钙铁铀钍矿。这些矿物都带有辐射，所以Peretti带备盖格计量器(Geiger counter)。经过缓慢而有序的扫描，在矿场中弃置的细小圆石堆内，发现高放射性的矿物，而我们只不过搜索了40平方厘米乘40平方厘米的范围。由于量度度数超出了上限，计量器发出的哔哔声，引起了其它队员的注意。我们找到一颗大晶体，并送往实验室再作分析。Hahn与Eugene也参与搜索，他们注意到盖格计量器越靠近某一样本就响得越急。我们仪器可量度的辐射范围只有15厘米的直径距离(B-及少量Y射线)。只需两分钟就找到另一个样本。我们将5公斤的岩石样本包装好，再转送至实验室(图19)。



图16.两个强壮的马达加斯加男子正在洗选大量泥土，以取得来自冲积床的巨型鹅卵石，而当中主要含有片麻岩、角闪岩、辉长岩，但无碳酸

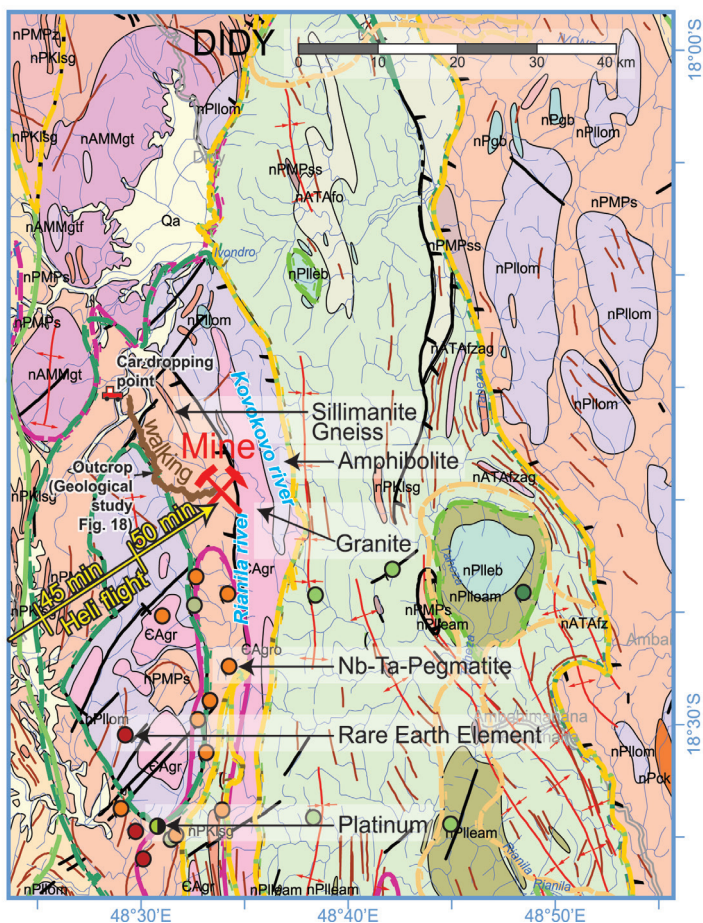


图17.一幅展示马达加斯加Didy矿场「理想地质世界」的地图。矿场位处变质岩，含有片麻岩、角闪岩、石英岩、互层硅线石片麻岩（Mananpotsy复合岩层）、混合岩石榴石及含黑云母的邻斜长角闪岩。含有宝石的区域在西面（约东经48.50度），中层岩层是夹杂片麻岩及闪岩的Beforona岩组，甚至可发现大型的辉长岩（东经48.45度及南纬18.37度）。铌-钽矿化作用是矿场内岩石的主要差异。从地图上可见存在结晶花岗岩。Ambalavao岩石群围绕采矿区，含有各类岩石，包括深熔花岗岩及混合岩。它们部分是熔岩，是低层高变质大陆地壳的典型岩石。现时证实Mananpotsy硅线石的片麻岩在这区域受高度变质作用（高温）。地图内估计的岩石种类（闪岩、片麻岩及石英）实际上是从采矿区采挖得来（图19）。当地出现大量的铁-钽-铅-铋-锆-钽-铀-钇-铈-氧化物矿物（图20）和内含物（图26A），显示亦发现热液（大有可能与侵蚀有关）的痕迹。注意：地图上的考察路线及研究露出地面岩层的地点（图18）。蓝宝石及红宝石形成的可能情况有别于马达加斯加Adranondambo及坦桑尼亚Winza（见文献1及4），可能与深成岩、不饱和硅的变质，及蕴含丰富铝的岩石高度变质而造成的流体和熔体有关。由于地图比例颇大（1比500,000），必须进一步进行小规模地质研究，以进一步厘清实际情况。我们收集所得的GPS数据中加入了矿场位置，并以名称标示可能藏有宝石的河流分布。图例经挑选编辑，并由法文翻译成英文。地图由Carte Metallogenique et de Prédiction des Gisements、Métaux de Base et Métaux Précieux、Feuille No6-Toamasina剪辑而成（见文献.3）。

高度变质而造成的流体和熔体有关。由于地图比例颇大（1比500,000），必须进一步进行小规模地质研究，以进一步厘清实际情况。我们收集所得的GPS数据中加入了矿场位置，并以名称标示可能藏有宝石的河流分布。图例经挑选编辑，并由法文翻译成英文。地图由Carte Metallogenique et de Prédiction des Gisements、Métaux de Base et Métaux Précieux、Feuille No6-Toamasina剪辑而成（见文献.3）。

图注			
<b>沉积及火山岩（及变质等值）</b> Qa 非特定冲积岩 <b>Betsimisaraka区</b> <b>Mananpotsy复合岩层</b> nPMPs Sakaniia 之地层构造 黑云母片麻岩±角闪岩及角闪岩连同石英岩混合物/石英岩晶体、石墨晶体 nPMPss ±硅线石±石榴石岩及少量钙硅酸盐岩大理石 硅线石片麻岩 <b>Antananarivo区</b> <b>Mananpotsy复合岩层</b> nPMPz Ambatondrazaka地层构造 黑云母片麻岩（±硅线石±石墨） 连同石英岩晶体及角闪岩晶体 Cu铜 Ni镍，红土镍矿，非特定镍硫化物 Be铍，含绿宝石的伟晶岩		<b>火成岩（变质等值）</b> <b>Antananarivo区</b> <b>Ambalavao系列</b> CAgro 深熔花岗岩、自发形成 钾长石岩相 CAgr 未经鉴别深熔花岗岩/ 混合花岗岩 <b>Kiangara系列</b> nPKIsq 碱性花岗岩及正长岩质片麻岩， 多相分层、粗粒、且介质有区别的（黑云母正长花岗岩， 碱性淡色花岗岩及含石英正长岩） <b>Imorona-Itsindro系列</b> nPck 花岗岩及紫苏状的花岗岩或 紫苏花岗岩（未确定） nPleb 辉长岩 nPleam 辉长岩邻斜长角闪岩（未确定）	
<b>Tsaratanana复合岩层</b> <b>Beforona岩组</b> nATAfo 混合斜长片麻岩连同黑云母 ±角闪岩及花岗岩质片麻岩及 角闪岩晶体及斑状变晶片麻岩 nATAfz 镁铁质黑云母片麻岩，带状及 本地切变连石英岩、角闪岩及辉石， 变辉长岩及变超镁铁质岩 nATAfzag 角闪石片麻岩		<b>Betsimisaraka区</b> <b>Imorona-Itsindro系列</b> nPllom 混合角闪石±黑云母 石榴石正角闪岩 <b>Betsiboka系列</b> nAMMgt 角闪石闪长岩质片麻岩连同 ±斜辉石及闪岩石香肠 含石榴石及辉石变闪长岩； 当地形成紫苏花岗岩特性 nAMMgtf 镁铁质花岗岩变晶岩/ 镁铁质岩连同辉长岩状合成物	
Cr铬，非特定矿床类型 Fe铁，非特定矿床类型 Ni镍，非特定矿床类型 EGP冲积土 REE稀土元素 非特定矿床类型 Sn锡，非特定矿床类型 Nb-Ta钽钨化合物，含柯钽矿 非详细指明的矿床类型			



**19:00** Eugene 帮忙 Hahn 快速搭建好营地。营地上建有登山专用的两层帐篷和高科技蚊帐，他们还清理附近的石头和树枝，弄平地面。火把引来蚊子和飞虫。树木散发湿气，在雨林中形成了特有的生态系统。寒夜免不了带来雨水。搬运工人拿出装备搭建营地，在几棵树之间盖起一小片塑料，以遮挡夜雨。这夜，他们在蚊帐上再放置几张被单，但只能盖住约60%的面积。

## 2012年5月18日星期五

**早起赶行程** 午夜时分左右，大雨滂沱，计划需要更改。我们决定早上4时出发。大雨可能令泥泞小径更危险。Peretti 误把存有放射性样本的背包当作枕头，感染了少量辐射。可幸样本已密封，没有造成污染。

**上午6:00** 一瞬之间，晨光骤然照亮黑夜。大自然景观令人惊叹。昨夜雨水形成的雾气弥漫整个山头。雄伟而壮丽的树木在这马达加斯加自然奇境中耸然而立。景色令人目炫神迷。此处能俯瞰全世界最大红宝石与蓝宝石的出产地——这里充满富有异国情调的动植物，狐猴和稀有雀鸟叫声不绝，实属人间天堂。

## 岩石形态的野外地质研究

(<http://www.gemresearch.ch/video/Didy3.htm>)

Peretti 对种类繁多且颜色鲜艳的岩石形态(图18A/B)感到惊喜，他细察片麻岩的倾斜度及角度，并收集岩石样本。我们在小径上某几处发现小规模采矿活动的痕迹，显示矿工认定此地为蕴藏蓝宝石或红宝石的原生岩。岩石形态为具有不同化学性质的复杂层状岩；部分岩层内含闪烁的小辉石，但已受严重侵蚀，因此未能采集鲜明样本。在岩石层可见到有趣的香肠结构，显示颗粒体积增大，极有希望形成体积较大的蓝宝石。这些岩石的准确位置已记录于综合掌上型GPS，摄影机内的综合GPS则拍摄珍贵的相片。

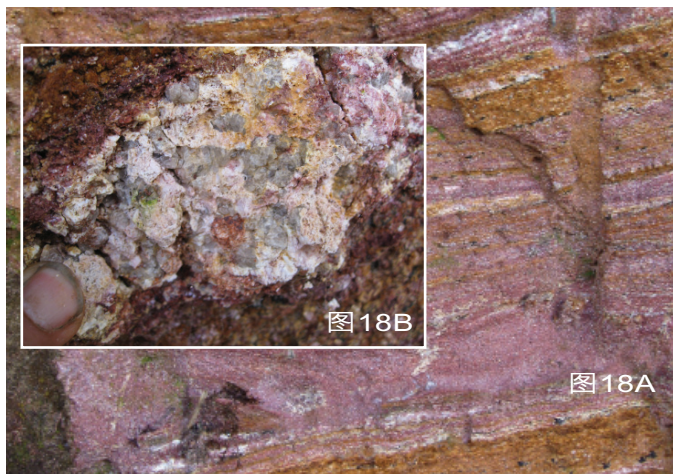


图18A距山坡矿场数英里以外（标注于图5）一块露出地面的岩层，岩石经过极端地壳构造，一直延伸，其风化色泽显示出内含各类的化学成份。除部份矿物质（如可能为辉石或闪石（见图标示））之外，只有石英层可抵受剧烈风化。图18B插图所示于若干范围内经过地壳构造形成坚固的香肠结构岩石，且颗粒体积增大。假如红宝石及蓝宝石是由于变质而形成，岩石这种状况对其形成甚为有利及属必须。矿工于此地点试图采矿，但他们的经验令他们最终认为此地不会有丰富收获。



图19图中显示河床上发现的闪岩及片麻岩。岩石类别是根据地质绘图（图17）估计得出，在一般情况下是可能形成蓝宝石及红宝石的优良源头。此处只是冲积层的一部分；尚未发现含有宝石的原岩构造。（GRS岩石收藏）

### 矿场补给

早上8:00，越来越多矿工和村民经过我们，前往矿场(图6)。我们离开时，他们进入矿区，带来补给品。他们利用细树枝和金属棒，架起多个大袋，当中放满米、食油、药品及香烟。我们亦以所带入的食物，估算矿场的人口。我们向搬运工人攀谈，得知他们搬运的东西。然后我们根据每人每日消耗5,000卡路里得出算式。透过计算搬运人数及查询他们的货物，我们估算每日约有450人向矿场运送2吨消耗品(包括活牛)。矿场大约有5,000至10,000名矿工。

每名搬运工人平均运送20公斤至40公斤的货物。我们其后得知，在矿场内，每包米的售价是30美元，比起正常价格高出三倍。在矿场的人们不但在追寻梦想，亦在付出巨额的个人投资。回想起来，我们曾经估计昨天只有约30人离开矿场。只有商人质询我们何时离开。一群20至30名打算进入矿区的矿工告诉我们的搬运工人，他们曾经听说外国人会来关闭矿场，这个揣测令人担忧。我们向他们保证我们无意关闭矿场。Hahn以法语解释，一如他们，我们的业务也依赖采矿活动。

### 到达首都ANTANANARIVO

10:20，我们搭乘直升机，经过一小时航程后(图3)，到达Antananarivo, Hahn请机师拿着飞行日志的「飞行卡(la fiche de vol)」让他拍照，否则我们永远无法发现这趟直升机航程是骗局。Peretti为额外飞行里数支付2,000美元附加费，但当中大部分行程是未经批准的。

**免遭伏击。**司机驶出直升机场大楼，途中车窗突然爆裂，车子只好停下，右边车尾玻璃窗碎裂成碎片，只差20厘米便击中Peretti头部。Hahn勒令司机立即离开，思忖我们可能遭到射击。事件惊动了直升机场，警察到场了解情况，30分钟内就缉拿投掷石头造成骚乱的妇人。但是，我们觉得这次事故解决得太快，好像造假。有关人物或当局应该早获通知，所以必需在我们视线范围外解决，真相永远不得而知。Peretti的颈及手臂插了多块玻璃碎片，在回酒店的余下车程内都动弹不得。电话响个不停，有人希望我们检测大颗宝石，

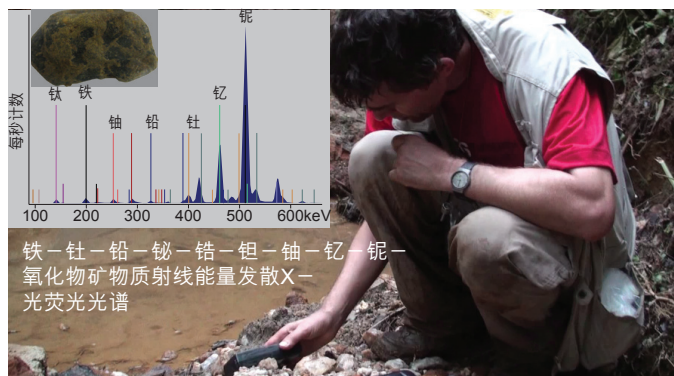


图20. Peretti以盖格计量器检测矿场的一处剩余砂砾层，并发现高放射性矿物质(铁-钷-钍-铀-钷-铯-钡-镧-铈-镨-钕-铈-铉-铪-氧化物矿物质)。



图21.其中一位作者(AP)手上的是一套介乎7至超过14卡的八颗经琢磨的红宝石，价值不菲，估计市值超逾1千万美元。其中超过10卡的宝石中有两颗归类为GRS一类「鸽血」颜色类别。马达加斯加Didy红宝石一夜之间跻身为现今世界掘出的最大红宝石之列，既瑰丽又稀有，可媲美最顶级缅甸红宝石。



图22.近镜头拍摄来自马达加斯加Didy逾7卡的红宝石，晶莹剔透，肉眼完全看不见内含物质。这些来自Didy的红宝石并无绢丝分布(绢丝分布可产生肉眼可见的白色折射，可能影响宝石净度)。这些红宝石毫无瑕疵，因此很容易在矿场私人造宝石混淆其中。(照片：W.Bieri. © GRS)

另一些人则想赚取金钱。除了参考样本(图26A-D)外，所有宝石不得出口，我们踏上归途，乘飞机前往曼谷。登机检查时，Hahn被海关抽查，连同四名似乎来自中国内地的乘客，一同接受海关抽样检查手提包。Hahn告诉关员，毋须搜查，这样做会弄乱他的物品，奇迹地，海关放行！

**后记** 两日后，矿区警员前往Ambatondrazaka，而那些非马达加斯加人的商人停止他们的买货业务、暂时撤往首都待几天以避风头。由于警员亦在采矿地区进行搜捕，矿工必须离开。现在，矿工及商人都已返回矿区，或迁往森林另一相若地区继续谋生。

与我们搭乘同一架直升机的部分旅客因直升机飞行未经批准的航线而遭受调查，并请求Peretti给予批文副本。Peretti提供有关文件解决事件，但他并未留意，分发名片及在未经授权矿区内非法兜售宝石的事件仍在调查中。名片上印有其名字的男人已遭监禁，需要付出巨额保释金方能保释。GRS在这次考察旅程的行程中遭到骑劫，如何获得赔偿，仍未有定案。

**红宝石价格破世界记录** 我们得知，于6月份，香港珠宝首饰展览会中，一名商人以一百万美元售出一颗闪烁动人的7卡红宝石(Didy)(图14)。这些红宝石每颗都是大自然瑰宝，实实在在打破了记录。GRS在交易中是率先在矿场内已见证宝石开采活动的唯一一家公司。

**GRS新闻发布，10月22日**  
(<http://www.gemresearch.ch/video/Didy6.htm>)  
GRS于9月份在香港珠宝首饰展览会中举行名为「破世界记录鸽血红宝石新发现」的研讨会，会上公布多项新发现。(见www.jewellerynewsasia.com—关键词：GRS)

**投资者获取采矿权，10月30日**  
以下资料来自宝石市场：一名主要投资者(GF)已取得山谷较高位置的采矿权，而一家由非马达加斯加人参与的私人投资集团则取得山谷较低位置的采矿权。双方均聘请来自Didy的当地人士于矿场工作。



图23.一套来自马达加斯加Didy的蓝宝石，介乎5至超过10卡，当中有只会产自斯里兰卡、缅甸及马达加斯加Ilakaka的典型GRS一类「皇家蓝宝石」。(照片：W.Bieri. © GRS)

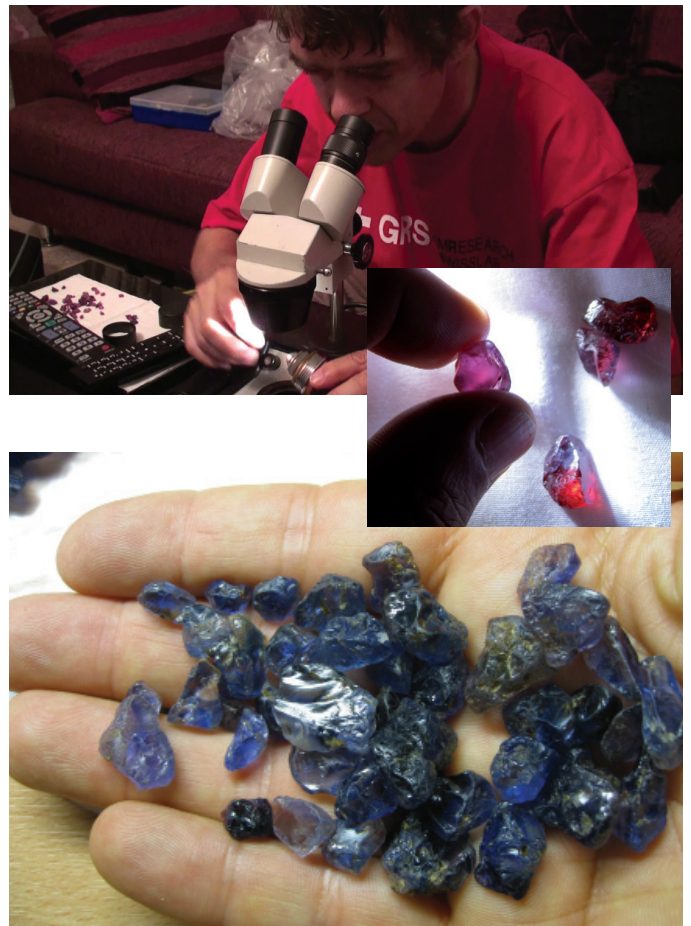


图24. Peretti使用携带便携式显微镜目测Ambatondrazaka商人带来的众多红宝石及蓝宝石。因这些宝石具备钛铁、锆石簇、蓝色带状分布，但并无绢丝，透过显微镜能轻易将这些宝石从所有其它地区的红宝石中区分出来，即使于坦桑尼亚Winza的相似宝石亦能区分。对于含有大量负晶体及二级液体特征、单独锆石、黑色钛铁簇、导向非闪石针状物以及一般缺乏绢丝的蓝宝石而言亦是如此。(文献. 2)

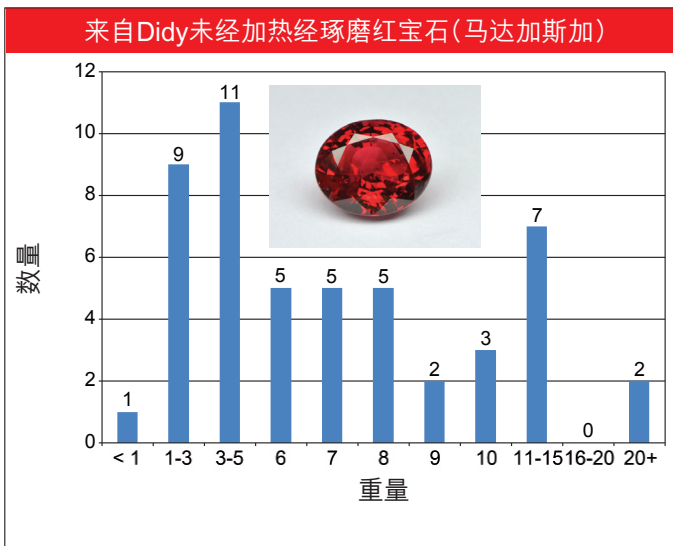


图25. GRS于发现红宝石之后3个月对25颗来自马达加斯加Didy的红宝石进行测试所得出的统计数字。统计数字显示，只需一段短时间，便发掘出两颗超过20卡的瑰丽红宝石。这些大颗红宝石通常为缅甸Mogok等大型矿场花数十年开采得来的优质副产品。GRS统计。

投资集团现时在森林中聘有至少两名代理监管营运，由于一颗128卡的蓝宝石原石从这两个矿区以外找到并送往GRS作研究，因此于这两矿区以外进行额外采矿。产地为Didy的宝石亦再次送交实验室作检测。

文献1. Adolf Peretti、Francesca Peretti、Anong Kanpraphai、Willy Bieri、Kathrin Hametner及Detlef G ü nther。发现温莎红宝石(Winza Rubies Identified)。收录于Contributions to Gemology (2008年版) 第7至97页。

文献2. Adolf Peretti、Willy Bieri、Kathrin Hametner、Lawrence Hahn及Detlef G ü nther (2013年)。来自Didy (马达加斯加) 破世界记录的红宝石及蓝宝石以及来自Kataragama (斯里兰卡) 的全新蓝宝石矿 (World-record rubies and sapphires from Didy (Madagascar) and the new sapphire mines from Kataragama (Sri Lanka))。地积学与宝石学考察报告(Expedition Report, Geology and Gemology)。收录于Contributions to Gemology第12号，印刷本。

文献3. Carte M ê tallog é nique et de Pr ê diction des Gisments, M ê taux de Base et M ê taux Pr ê cieux, Feuille No 6-Toamasina (2008年) (J. Ramarolahy, D. Rakotomanana, B. Moine, E. Ortega, L. Chevallier, F. Hartzler, G. S. de Kock, S. W. Strauss et, A. F. Randriamanantenasoa, J. Naden, L. Noakes, Edit é e par : 英国地质调查局 (British Geological Survey) Keyworth, 诺丁汉, 英国) MINIST È RE DE L' É NERGIE ET DES MINES Projet de Gouvernance des Ressources Min é rales (PGRM)

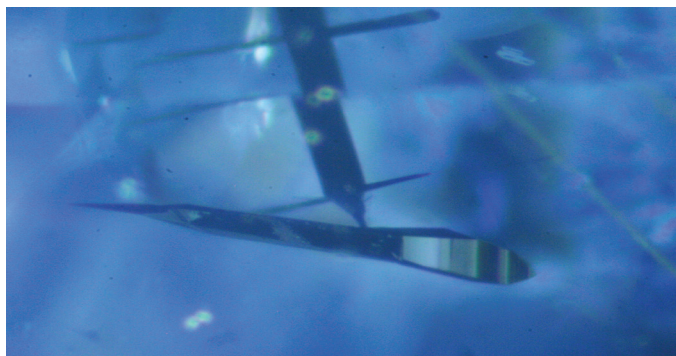


图26A.于非洲马达加斯加戴迪 (Didy) 出产的蓝宝石，内藏大型的冰锄状锰钇铌矿物夹杂物。此发现证实了蓝宝石的形成与伟晶岩铌钽矿床有着密切关系。

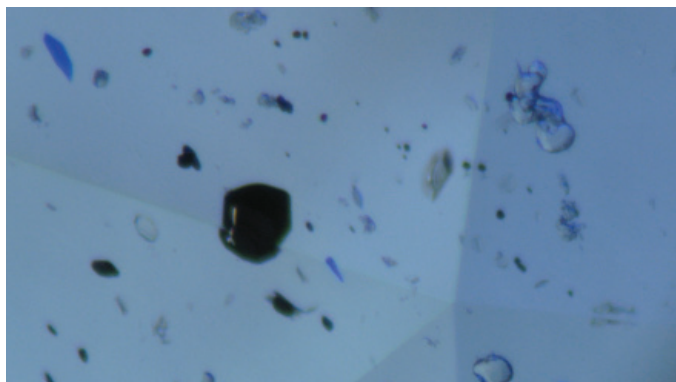


图26B.于一颗超过5卡的Didy蓝宝石中发现含有云母、钛铁及锆石簇 (GRS收藏)。这些矿物通常可于矿场的闪石—片麻岩层中找到。钛铁经GRS于2012年7月以SEM-EDS分析获得确认 (瑞士University Fribourg地球科学系SEM—实验室M.Meier)。

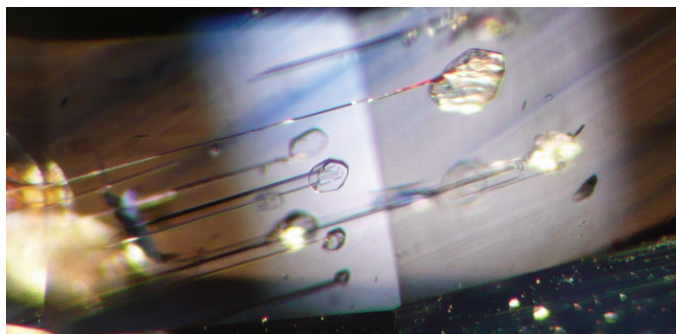


图26C.在液体内含物空间长出韭闪石针状物，并可定向生长，渗透整颗蓝宝石。这是作者之一 (AP)首次目睹蓝宝石内部的现象，显示蓝宝石在剧烈热液状态中形成。这颗蓝宝石亦呈现颜色带状分布，带状分布的终止情况并无规律。一如来自马达加斯加的其他蓝宝石，这颗宝石并无呈现此奶白色部分。

文献4. Edward G ü belin and Adolf Peretti (1997年) : 产自马达加斯加东南面Adranondambo矿区的蓝宝石(Sapphires from Adranondambo mine in SE Madagascar) : 交代硅卡岩形成的凭证(evidence for metasomatic skarn formation)。宝石学期刊 (Journal of Gemmology) 第25卷第7号第453至470页。

文献5. 亚洲珠宝—生活秀 (Jewellery News Asia — Show Daily) 2012年9月24日, 第10页。

GRS 谨此向以下各方致谢: Y. Group 让我们发现Didy, 并提供现场基建及款待; Tom Cushman 策划取得政府及当地通关批文, 并安排交通及整理数据; 马达加斯加政府及Didy 市长发出通关批文并提供当地支持; Gem Paradise 及朋友找寻机会; 所有当地矿工; Assist Aviation; Ghambi; Diana Jarrett; 另外特别鸣谢努力不懈的 搬运工人以及拯救我们脱险的Eugene。最后同样重要的, 是GRS团队, 在实验室面对繁重工作时紧守岗位, 令人敬佩。



图26D.来自马达加斯加Didy的经琢磨红宝石内发现折迭羽状斑疵。这种羽状斑疵一般预期在蓝宝石出现, 而红宝石则并不会会有此斑疵。(插图: W.Bieri & A.Peretti, © GRS)

# GRS



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# 馬達加斯加Didy礦區破天荒發現紅·藍寶石：源產地勘查

作者：Adolf Peretti博士 (FGA FGG) 及Lawrence Hahn (GG)

GRS實驗室 (<http://www.gemresearch.ch/video/Didy5.htm>)

於2012年5月，一位客戶專程從馬達加斯加飛往曼谷的GRS實驗室，送來兩大顆優質紅寶石（圖1A），請實驗室進行測試。

客戶表示，馬達加斯加傳聞，指當地的晶石其實是人工合成，所以他憂心忡忡，必需先確認晶石為天然真實的，他的集團方會進一步投資。

實驗室利用能量發散 - X光螢光光譜儀 (ED-XRF)、傅立葉轉換紅外光譜儀 (FTIR)、紫外 - 可見光譜儀 (UV-VIS)、拉曼光譜 (Raman) 及顯微鏡測試樣本，發現該大顆晶石確實是天然且未經加熱處理。為肯定這些晶石是來自客戶所疑慮的礦區，兩位作者開展冒險旅程，親身前往



圖1A及B.來自馬達加斯加Didy超過60卡的寶石級原石，乃琢磨成超過26卡的瑰麗紅寶石（圖右）。這些瑰麗紅寶石的售價創下世界記錄，更令人趨之若鶩、觸發搶購潮。除非另有註明，否則所有圖片均由作者Peretti及Hahn拍攝，而版權則由GRS所有。 (<http://www.gemresearch.ch/video/Didy4.htm>)

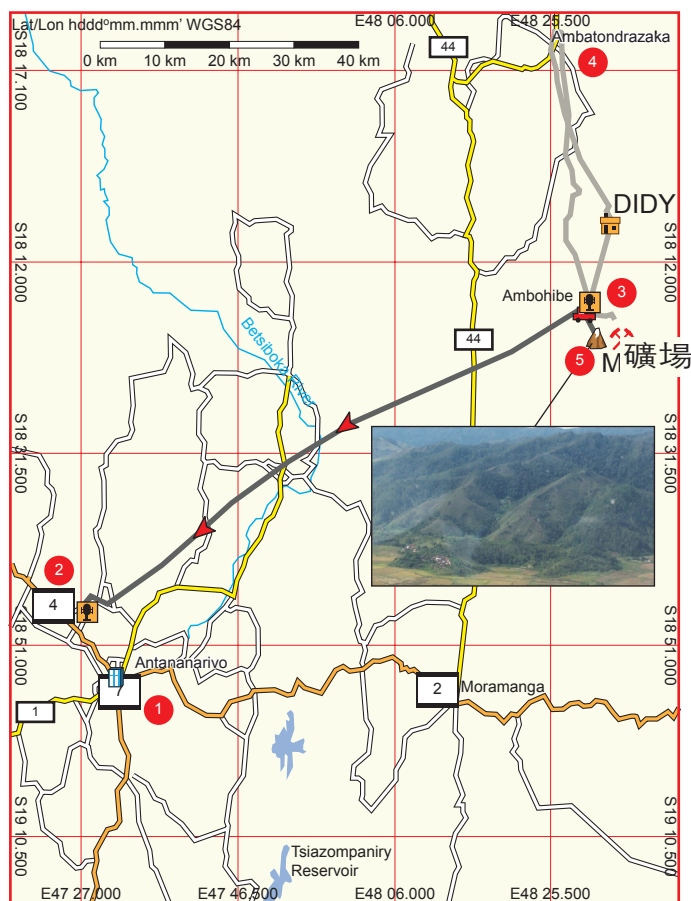


圖2.我們自家的GPS所記錄直升機前往礦場的一節詳細飛行地圖；3-4.天氣良好，我們乘坐航班從Ambohibe前往Ambatondrazaka，機上電腦故障，所以這段航程由Peretti領航。（圖5）4-3天氣惡劣，並無使用GPS，航機隨著地形飛行，前往Ambohibe；3-2途經雨林回程到首都（1是首都Antananarivo）。



圖3.從Didy礦場考察歸來後，作者Peretti（左）及Hahn（右）拍下照片，留住令人難忘的一刻。回程時的考察物品重量超過150公斤，包括可攜式寶石實驗儀器及露營裝備。飽歷16.5小時艱辛叢林步程往返礦場後，兩名作者赤著無比酸軟的雙腳；而爬山鞋亦沾滿泥濘。（照片：Cushman © GRS）

往晶石的來源地，勘查礦區實況，以獲得第一手資料。他們拍攝當地採石熱的情況，並從礦區採集岩石及礦物樣本以作比較，藉此瞭解地底下鋼玉礦床形成位置的地質狀況。

他們也要獲取重要的紅藍寶石標本以作進一步研究（圖7A及封面）。在馬達加斯加每次進行實地考察，都涉及安全風險，物資運輸會遭遇種種困難，更經常要有技巧地與當地居民及政府談判。就單單前往當地，首先要克服連串挑戰。Peretti憶述：「首先坐12小時汽車到達Ambatondrazaka (Amba)，接著，若然天氣良好，駕車3至5小時，便可到達Didy；但最後還需步行至少一日，方抵達目的地。然而，在這個未知國度，不能保證能夠成功通過看似受保護，但又阻隔重重的雨林，到達首都東北部。」因此，Peretti決定乘搭飛機較佳，並獲得一位當地前珠寶商幫助，安排一輛直升機由Antananarivo出發，飛越國家公園上空，再確定礦區位置，及標繪明確的全球定位系統(GPS)座標。然後，他們會決定最近的降落地點，再前往Didy，以向當地政府辦理通關批文，繼而選擇合適交通工具，向目的地進發。航空公司在Amba設置加油站，備有400公升汽油儲量，而從他們離開Antananarivo起，

至飛往Amba的12小時行程中，均有直升機機員隨行協助（圖2）。

Peretti考察日記中摘錄的內容揭示了實地考察期間所發生引人入勝的故事。



圖4A



圖4B

圖4A.距離礦場南面10公里的花崗岩石形成一個山脈（較能抵受風化）。（見圖17的地質學）。

圖4B. GRS飛越Zahamena-Ankeniheny受保護森林時拍下馬達加斯加Didy礦場營地的空中照片。插圖為Peretti於機上GPS電腦故障時負責領航。

## 2012年5月14日星期一

不久前，GRS實驗室接到消息，表示政府已封鎖了一個有約30,000名礦工的礦區，以防止外來人進入。距離最近的村莊步程需3小時。當地人或政府當局設置的路障，加上滂沱大雨及惡劣路況，使得我們舉步維艱，以致需要幾乎15個小時車程，才能從Antananarivo（名為Tananarive首都）抵達最接近礦區的市鎮Didy。

## 2012年5月16日星期三

Zahamena-Ankeniheny是推測採礦活動所在的必經之路，雖然未成為國家公園，但已獲當局建議納入保護區域，故特別稱為國家公園，劃入受保護區域類別內，以防止環境被破壞。

## 飛越新礦山

<http://www.gemresearch.ch/video/Didy1.htm>

飛機在雨林覆蓋的懸崖峭壁上空越過，壯麗景色令人嘆為觀止（圖4A）。飛行40分鐘後，機師宣佈我們已抵達GPS座標所在位置，地面上聚集了一群人（圖4B）。這個藍寶石區域稱為Didy，官方名稱是Ambatovolona。

沿著河床在礦區上空盤旋，我們看見礦工們正忙著挖掘與洗選。地面上幾乎每個人都停下手上工作，目不轉睛地盯著直升機。我們發現第二個面積較小的地方，意味著礦工現正擴大採礦範圍，開發不同領域。我們看到百多個藍色帳篷，究竟這裡實際上有多少礦工？這兒看來與我們之前所推斷能容納30,000名礦工的營地並不相像，反而像是待了5,000至10,000名礦工，而且採礦毫無組織，只是一大群人各自以「先到先得」的方式工作。

盤旋幾圈過後，我們已拍攝足夠的相片及影片，不希望繼續打擾礦工，所以Peretti示意機師離開這一區，尋找最近的降落地點。礦區延綿幾座小山，在雨林內橫跨約5至10公里，但礦區附近似乎並無可以降落的地方。未幾，我們發現森林邊緣停著多輛汽車，車主很有可能是寶石買家。接著我們發現一座小山，山上有6所房子圍繞著陡峭山道而建，乍看像是在山頂上架設要塞的中世紀村莊，我們稱之為「鷹之窩 (the Eagle's Nest)」，之後得知其實際命名為Ambohibe。

可能降落的最近地點距離鷹之窩旁邊礦區8分鐘機程。我們看到一塊收割完的水稻田，土質已變硬，有幾頭牛在閑溜。我們嘗試在該處降落，並保存GPS座標以方便回程。於是，我們決定先研究這兒的環境，再前往Didy。

在Didy降落時，我們碰見一大群可愛的孩子和看來友善的當地人，孩子們對當地長輩謙恭順從。顯然，這群孩子是第一次見到直升機。村長解釋說，所有身強力壯的男人們都去了森林採礦，把稻田裡的繁重工作留給婦女們做，導致今年收成慘淡。我們與當地政府商討，獲得重要批文，才得以參觀礦區。

隨後我們抵達Ambatondrazaka。在出發前我們聯繫好一家可靠的機構，在我們到達後給予我們相當多的細小紅、藍寶石，供參考採

樣。我們利用可攜式實驗儀器（圖24）檢測了一些大顆紅、藍寶石標本，並瞭解到礦區確實存在，更能出產大顆、未經加熱且色彩鮮明的寶石。我們開始嘗試設法進入礦區，但日益感到焦慮，我們也許期望過高。「對於認真的地質考察工作，留在礦區單一日的行程根本不足夠，另外，礦區會否證實蘊藏量不多，只屬曇花一現，而並非藏量豐富，能真正帶動採石熱潮？」我們得知一個很實用的方法－「買香煙給礦工們」。Peretti回想起，在偏遠地區Ilakaka工作的礦工總會問同一個問題「有香煙嗎？」，尤其是拍照及錄影之時，他們都期待得到「回報」。

### 2012年5月17日，星期四，上午8:00

陷入被俘虜的險境 繞著較低雲層盤旋後，我們終於降落地面，當地居民看上去非常冷酷，充滿敵意。他們包圍了我們，並用四驅車堵住

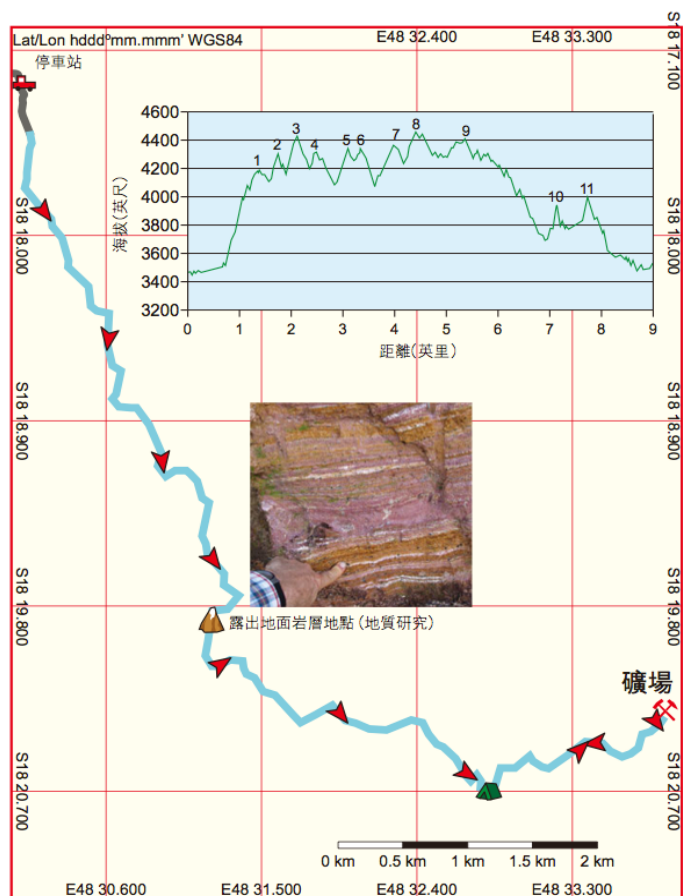


圖5. GPS追蹤穿越森林前往礦場的行走路線，包括所行進的海拔圖。圖中顯示前往礦場途中首次攀登峭壁及橫過約14個小山（峰）。紅色箭咀標示每隔約一小時停下來喝水及進食。地質圖中顯示路線。（圖17）



了我們的出口路線。一位並非馬達加斯加國民的商人說，「當地的『首領』索價1,000美元，作為降落權費，另外2,000美元作為通行稅！」無視我們從Didy獲取的官方批文。我們連同直升機都被他們團團包圍。我們協議不會答應他們的「開價」，經過一輪協商，「開價」降至1,000美元，才打破了僵局。我們從一個我們命名為「停車站(Car Drop-off)」(交通工具能到達的最遠地點)(圖5)的地方開始進發。這一停車站聚集了各式各樣四驅車，車主為一幫當地的寶石買家。當地人紛紛向我們投以敵對且愠怒的目光，直至意識到我們並無惡意，氣氛才緩和起來。我們事先安排了司機翌日在這裡接送我們，但他卻失蹤了，再也沒有碰見過他。

**徒步遠征** 我們在GPS設定礦區及這停車站入口的座標後，開始了長達16個半小時的步行。我們帶同一個嚮導還有4個搬運工人幫忙攜帶設備，包括帳篷、食物及水，而我們則行攜帶攝影器材。

起初，我們走得很順利，以每小時約行進6公里路程。我們滿有信心，沿著旁邊種滿稻米的河谷小溪前進。再往前走，小路變得雜草叢生。我們遇到兩個人，他們扛著又大又重的原木(或許是花梨木)，朝鷹之窩的相反方向走去。這些原木看來像是在受保護雨林內的工廠剝皮、成型、備妥、並由人工搬運以作出口的。這些非法伐木工人大概亦是率先發現寶石的。



**圖6.一名滿身淤泥的礦工為礦場補給重量達30-40公斤的米、油、小河魚及香煙。由於淤泥粘腳，這名礦工的鞋子散失，只好赤腳行走。**

嚮導Eugene兼任保鏢。我們僱用的員工需要補充體力，於是停在附近一間小屋吃一碗魚飯，好好裝備自己。此處乃受保護雨林的入口，已有另一群買家聚集，他們似乎未能適應艱苦的徒步旅程，正在一間臨時搭建的小屋內收聽收音機節目放鬆休息。我們將要捱過漫長的登山旅程，沿著每段200米的路徑不斷上山下山。Eugene殿後，確保無人迷路或受傷。山路崎嶇難行，但總體是向高處進發(圖5-海拔圖)。

## 未經批准的宣傳舉動 直升機航班，上午11:34，Ambohibe

回家後，我們細閱機師的飛行日誌，發現在離開降落地點後2小時，直升機組人員曾讓一位陌生人登機。

直升機從Ambohibe起飛，按指示返回Amba，但這次卻未經批准接載了一名盲人乘客。機師記錄了每一位乘客的姓氏與名字，唯獨盲人乘客只以其姓氏「A」識別。我們假定機師受賄了。據情報，盲人乘客正是之前索求通行稅費的「首領」。整個旅途結束之後，機師承認在未經出資人許可下，竄改乘客名單及路線指示。這一組特立獨行的人，在礦區上空飛過時，一邊拍攝相片一邊從直升機上拋下商業名片。這個魯莽的行動不幸地令GRS未能獨家記錄當地情況，每個在礦場的商人都提高警覺，害怕外國人入侵他們的地盤。那些商業名片意味著礦場即將公諸於世，令危機增加。機組人員是否為了商業利益，就能輕易被利用，做出不道德的行為？他們是否被A脅迫，所以一概保密？抑或為了策略結盟而幫「A」一把？極有可能的是，其他非馬達加斯加人預先計劃好這齣宣傳鬧劇，藉以加強他們的購買力。

直升機來來回回飛了好幾遍，Peretti和Hahn卻毫不知情。到底他們是否仔細選擇路線，以避免被發現？

## 在通往礦場的叢林小徑上 午飯時間，中午

旅途中，搬運工人和嚮導沒有攜帶糧食，只帶了一瓶水共用，途經河流時補充食水，我們最終需要與他們分享三分之二的糧食(圖8)。

與白種人截然不同的，他們在旅程中幾乎不流汗。雖然搬運重物，但他們在這裏成長，早已習慣當地炎熱的天氣。

山路土地泥濘，草木叢生，地勢越見陡峭；我們的速度減慢，每小時只能走2公里的直線距離。路上遇上二十多位友善途人，都多次問我們是否乘直升機來。我們解釋我們是地質學家和遊客，並非記者和買家。我們不知道他們所指的是數小時前他們見過的直升機。有些人向我們兜售寶石，但我們決定甚麼都不買，因為錢財不可露眼。甚麼都不買其實



圖8.這圖片展示距離礦場約5英里森林中間的休息點，配備小型野外煮食用具，他們以當地河流當作水源及洗澡的地方。照片展示Peretti（紅衣者）與攜帶設備的搬運工人。

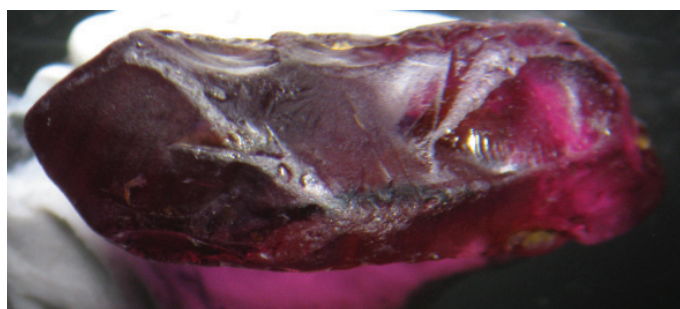


圖7A.產自Didy的典型4卡紅寶石。這並非碎石，而是完整保存且未經琢磨的原石。紅寶石形成時摻雜其他礦物，並留下各類影響價值的痕跡。並無發現任何經河流飄流的跡象（概無圓潤的邊角和刮痕）。石塊上只有與礦物（必須含鈦）連接的一邊才會出現藍色帶狀分布。（Hahn的收藏品）



圖7B.左面是85卡未經琢磨的帕德瑪(Padparadscha)藍寶石，非常清澈亮澤，估計價值超過1百萬美元。另一顆是價值不菲的經琢磨18卡帕德瑪藍寶石，以正面向上及側面展示。這顆產自Didy的帕德瑪藍寶石於放大鏡下毫無瑕疵，橙色與粉紅色完美融合，品質不受高熱影響，並無任何帶狀分布。這是從事測試工作以來遇過最大顆經琢磨的瑰麗帕德瑪藍寶石。

是很為難，我們實在很想從出產地得到相關樣本。不過我們其實無權擅買寶石，也不想馬達加斯加商人認為我們會搶走他們的生意。有些人開口求售，但本意並非真正售賣寶石，他們實際上是經紀，只是想試探我們是否在尋找寶石。我們強調我們是在私人公司工作的瑞士和德國公民。謠言盛傳美國記者將至－當地人明顯不歡迎記者。當地礦工和商人對直升機不斷到來感到憂慮。

我們過了兩條河，並兩次接納嚮導的建議載我們過河，免得衣履盡濕。我們很滿意搬運工人的建議。共享糧食後，他們和我們團隊一同上船，而且幫我們搬運重型裝備，以示尊重。

### 15:30 在叢林發現通往礦場的入口

<http://www.gemresearch.ch/video/Didy2.htm>

在通往礦場前的最後一片高地附近，我們在用作洗選的小池塘旁邊，看到外露的巨石和洞口，這是我們首次發現荒廢礦區的痕跡。細弱的河流顯然有異於其原貌，但我們卻並不擔憂。隨著熱帶雨下降，很快會恢復河流本身的流量。消失了的植物將再次茂盛起來。被沖走的岩石在四周堆積如山，其形狀小至沙粒，大至又黑又圓的巨石。很明顯，細小的沖積河床曾被開採。

河床礦藏毗鄰陡峭山坡，已被迅即開採殆盡，礦工於是另覓容易開採的地點。這個臨時搭建小屋已廢棄，顯示此地不只是用作勘探，更曾在一段時間內進行活躍的開採工作。

小徑越來越狹窄，並分散為幾條樹根叢生的狹



圖9



圖10

圖9.山谷較高位置的採礦環境，有每個可容納六至八人的帳篷、補給站（中間右面）、清洗泥濘的儲水庫、樹群下的採礦地盤及瓦礫棄置點。與於同一森林的伐木活動比較，採礦對大自然的損害屬輕微。（南緯18 20.31度、東經48 33.83度，3486呎）

徑。雨林內狹徑眾多，由於曾有數以千計的礦工路過此地，這幾條狹徑顯而易見。

### 16:00 寶石界一大發現

礦場入口的山坡上佈滿帳篷和臨時搭建小屋，雜亂無章，山谷中有無數的礦洞和溝渠。藍色的臨時帳篷最多可容納八人。我們小心收集這些資料，好等日後用空中監測數據來計算此地礦工的數目。期間，有些人不斷問，「你們在這裏做甚麼？你們是誰？你們曾坐直升機嗎？」我們可從發問者的服飾辨認到他們：沒有泥濘、穿鞋子、戴墨鏡及手持火把去探查寶石。他們想知道我們是否有意分一杯羹，危害他們的收益。

圖10. 2012年5月17日：於礦場被政府機關關閉前兩天，及大型投資者接管營運前數月，兩名作者Peretti及Hahn處於備受威脅的局面。考察行動至此，兩名作者遭受挑釁。（照片：嚮導Eugene）

許多有組織的礦工都由經紀聘用，經紀給予礦工少量信貸，如現金、工具或食物，而這些經紀不希望入侵者再出價招徠礦工。較大顆的寶石通常會轉送至鄰近中心，尋求更多出價，並售予出價最高的競投者。從礦場直接取得或觀察樣本極其重要，原因為這是百分百可靠的來源憑證。我們得以探查礦場內一些原石，肯定地證明其獨特的晶體習性。

16:10 我們向著礦場進發，十分鐘後仍然身處入口位置。山谷路面越來越廣闊，而深處為河流的源頭。礦場入口有一條內河連接主河流。再步進山谷，我們發現越來越 多礦工和房屋。我們估計實際挖掘範圍為礦場周邊約30%的土地，其餘尚未開發。這裡有些女士負責管理食



圖11.拍攝高解像DVD記錄片所在的平台位置，這段記錄片已於9月份香港珠寶首飾展覽會上在GRS研討會中播放。

物和日常用品，其他則是四處交際的商人。

### 礦場的拍攝平台

我們抵達一塊平地，附近有多組礦坑，旁邊設有洗選處（圖9、10、11及12）。每組有三至四人從小洞挖走泥濘，另外一人在洗礦處旁邊用籃子篩走污土。現在山谷已關閉，為免造成騷擾及步入高及膝蓋的泥濘當中，我們繼續在斜坡上行走。我們原本打算前往更下游的位置考察，但由於安全問題而令計劃改變。因此，我們只好花時間在開採活動上，這也是我們歷險的關鍵階段。

這次旅程好比一個世紀前採礦者經歷的加州淘金熱。不過，這次是探索歷來發掘出最大的紅寶石和藍寶石（圖14及16）。

### 礦場的演員

我們在此遇到多位「演員」，要求拍照。其中一人揮動粗木杖，用馬達加斯加語呼喝着另一邊的礦工，把自己當成礦場之王，亦有一些人走近，他們可能來自Didy鄰近地區。突然，呼喝聲響起，所有人目光投向相同方向。我們在此行並無發現碳酸鹽岩，但走近採集樣本實在太危險，所以我們其後在一個廢棄礦場內採樣。

**在拍攝地點遭遇煽動者及襲擊** 一名喝得爛醉的礦工走近Hahn，以法語無意義地嘀咕着。他嘗試解釋馬達加斯加人是如何窮困，並期盼救濟，更稱呼我們為美國記者。醉漢繼續說

着，但他不滿現場反應，一手拍開Peretti的攝影機。Eugene插手調停。醉漢把手上的小酒瓶作武器與Eugene對峙，礦工紛紛以馬達加斯加語叫嚷。一群人圍過來，我們不認為他們會站在我方。我們的搬運工人都噤若寒蟬，只能無助的旁觀。Eugene喝令醉酒礦工退開，警告其後果。他起初被我們保鏢的威勢震懾，但隨即故態復萌。醉漢向另一邊斜坡的礦場工地大喊：「美國佬！」又誣衊我們來此的目的，煽動其他礦工群起騷亂，以獲得更多支持。我們不得不離開此地。眾人都仍然認定我們是美國記者，會威脅他們的採礦生計。我們原定計劃靠近礦場紮營，這時看起來不再可行，遠離礦場才最安全。Eugene以其一貫微笑看着我們；我們也向他報以微笑，一起佯裝並不畏懼。三個搬運工人一如整段路程，靜靜的跟在我們身後，他們一直以來都努力幫忙。我們能真正全身而退，全賴Eugene虛張聲勢。幸好Eugene頭上的攝影機捕捉到某些最驚險的鏡頭。

**礦場中藍寶石原石面世** 我們離開時，「礦場之王」再次出現，風騷的向我們展示一顆重約10卡的藍寶原石（見封面照片）。它欠缺色澤，價值不高於200美元。有趣的是這晶體並沒有顯示其生長外形或習性。他放下身段，不再囂張，到此兜售寶石，可見200美元對他來說可算是大買賣。很難想像如果我們拿錢出來，開價求購時，會是怎樣的一個情景。Hahn讓他繼續站在我們身旁，使他以為我們會因為



圖12.礦工正在於樹下挖掘，掘到佈滿片麻岩、角閃岩、輝長岩及石英岩的第二沖積採礦礦床。

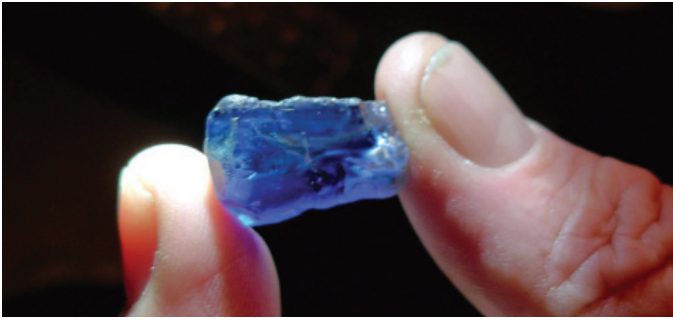


圖13.一顆來自馬達加斯加Didy的40卡GRS類「皇家藍寶石(Royal Blue)」原石，可切割成一顆10至20卡的寶石。估計批發價超過100,000美元。注意這顆藍寶石並非水晶碎石，而是在原生岩中形成，完全無水晶尖端的藍寶石原狀。

其平價藍寶石而對他另眼相看。回程時，藍色帳篷隨處可見，有些還搭建在深坑之上。全村有超過50個帳篷搭建在樹下，更設有臨時商店和賭桌，每一個帳篷聚集六至八人。有些小屋以兩層搭建，以一個較大帳篷覆蓋專用帳篷，以遮擋大雨。有些帳篷蓋着礦坑，以防護通往地底的圓柱形深洞。

#### 廢棄礦場的野外地質考察17:00

(<http://www.gemresearch.ch/video/Didy3.htm>)

我們決定以手電筒作照明，步行多一個小時，直至天黑，甚或步行整個夜晚。有些礦工可能於回程路上埋伏，以搶劫我們，所以速離此處實為上策。

17:20 我們抵達荒廢的礦區；這也是我們最後一次機會去檢視和收集岩石樣本。搬運工人和Eugene對於剛才發生的事交換了意見。這



圖14.於洗選處，我們遇到一位很有可能來自Didy、正在洗選的婦人。她的孩子應該上學但幫忙在側，他很大可能是在尋找鉑金，而非黃金，但他未必能發現鉑金的存在。（見圖17，發掘鉑金）



圖15.礦工在沖積床挖掘更深層，達到含有寶石的岩層。礦工挖掘岩層後，以籃子帶走岩石，再運到洗選處。

時，Peretti終於可以開始野外考察（圖20）。他手持小鎚，檢視沖積河床上的岩石樣本，很快就辨認出不同種類的岩石，如雲母片麻岩、角閃岩、輝長岩及石英巨礫。他深知藍寶石通常於出產放射性礦物的地質環境中形成，如方鈦石晶質鈾礦、鋯石或硅鈣鐵鈾鈦礦。這些礦物都帶有輻射，所以Peretti帶備蓋格計量器(Geiger counter)。經過緩慢而有序的掃描，在礦場中棄置的細小圓石堆內，發現高放射性的礦物，而我們只不過搜索了40平方厘米乘40平方厘米的範圍。由於量度度數超出了上限，計量器發出的咻咻聲，引起了其他隊員的注意。我們找到一顆大晶體，並送往實驗室再作分析。Hahn與Eugene也參與搜索，他們注意到蓋格計量器越靠近某一樣本就響得越急。我們儀器可量度的輻射範圍只有15厘米的直徑距離(B-及少量Y射線)。只需兩分鐘就找到另一個樣本。我們將5公斤的岩石樣本包裝好，再轉送至實驗室（圖19）。



圖16.兩個強壯的馬達加斯加男子正在洗選大量泥土，以取得來自沖積床的巨型鵝卵石，而當中主要含有片麻岩、角閃岩、輝長岩，但無碳酸鹽。



19:00 Eugene幫忙Hahn快速搭建好營地。營地上建有登山專用的兩層帳篷和蚊帳，他們還清理附近的石頭和樹枝，弄平地面。火把引來蚊子和飛蟲。樹木散發濕氣，在雨林中形成了特有的生態系統。寒夜免不了帶來雨水。搬運工人拿出裝備搭建營地，在幾棵樹之間蓋起一小片塑膠，以遮擋夜雨。這夜，他們在蚊帳上再放置幾張被單，但只能蓋住約60%的面積。

### 2012年5月18日星期五

**早起趕行程** 午夜時分左右，大雨滂沱，計劃需要更改。我們決定早上4時出發。大雨可能令泥濘小徑更危險。Peretti誤把存有放射性樣本的背包當作枕頭，感染了少量輻射。可幸樣本已密封，沒有造成污染。

**上午6:00**一瞬之間，晨光驟然照亮黑夜。大自然景觀令人驚嘆。昨夜雨水形成的霧氣瀰漫整個山頭。雄偉而壯麗的樹木在這馬達加斯加自然奇境中聳然而立。景色令人目眩神迷。此處能俯瞰全世界最大紅寶石與藍寶石的出產地－這裏充滿富有異國情調的動植物，狐猴和稀有雀鳥叫聲不絕，實屬人間天堂。

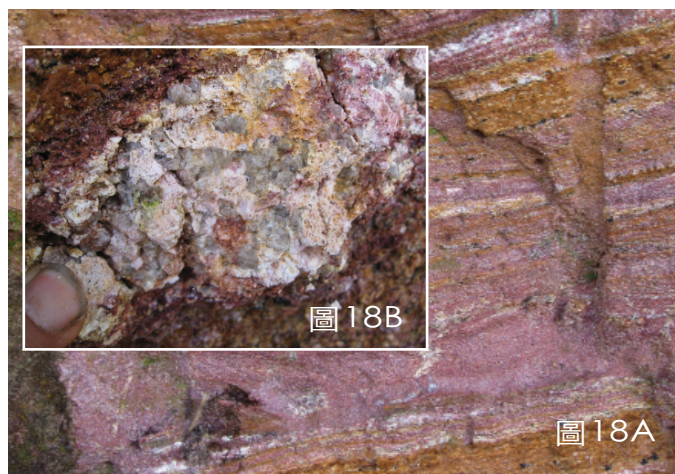
### 岩石形態的野外地質研究

(<http://www.gemresearch.ch/video/Didy3.htm>)

Peretti對種類繁多且顏色鮮艷的岩石形態（圖18A/B）感到驚喜，他細察片麻岩的傾斜度及角度，並收集岩石樣本。我們在小徑上某幾處發現小規模採礦活動的痕跡，顯示礦工認定此地為蘊藏藍寶石或紅寶石的原生岩。岩石形態為具有不同化學性質的複雜層狀岩；部分岩層內含閃爍的小輝石，但已受嚴重侵蝕，因此未能採集鮮明樣本。在岩石層可見有趣的香腸結構，顯示顆粒體積增大，極有希望形成體積較大的藍寶石。這些岩石的準確位置已記錄於綜合掌上型GPS，攝影機內的綜合GPS則拍攝珍貴的相片。

### 礦場補給

早上8:00，越來越多礦工和村民經過我們，前往礦場（圖6）。我們離開時，他們進入礦區，帶來補給品。他們利用細樹枝和金屬棒，架起多個大袋，當中放滿米、食油、藥品及香



**圖18A.**距山坡礦場數英里以外（標註於圖5）一塊露出地面的岩層，岩石經過極端地殼構造，一直延伸，其風化色澤顯示出內含各類的化學成份。除部份礦物質（如可能為輝石或閃石（見圖標示））之外，只有石英層可抵受劇烈風化。**圖18B**插圖所示於若干範圍內經過地殼構造形成堅固的香腸結構岩石，且顆粒體積增大。假如紅寶石及藍寶石是由於變質而形成，岩石這種狀況對其形成甚為有利及屬必須。礦工於此地點試圖採礦，但他們的經驗令他們最終認為此地不會有豐富收穫。



**圖19.**圖中顯示河床上發現的閃岩及片麻岩。岩石類別是根據地質繪圖（圖17）估計得出，在一般情況下是可能形成藍寶石及紅寶石的優良源頭。此處只是沖積層的一部分；尚未發現含有寶石的原岩構造。（GRS岩石收藏）





客，一同接受海關抽樣檢查手提包。Hahn告訴關員，毋須搜查，這樣做會弄亂他的物品，奇蹟地，海關放行！

後記 兩日後，礦區警員前往Ambatondrazaka，而那些非馬達加斯加人的商人停止他們的買貨業務、暫時撤往首都待幾天以避風頭。由於警員亦在採礦地區進行搜捕，礦工必須離開。現在，礦工及商人都已返回礦區，或遷往森林另一相若地區繼續謀生。與我們搭乘同一架直升機的部分旅客因直升機飛行未經批准的航線而遭受調查，並請求Peretti給予批文副本。Peretti提供有關文件解決事件，但他並未留意，分發名片及在未經授權礦區內非法兜售寶石的事件仍在調查中。名片上印有其名字的男人已遭監禁，需要付出巨額保釋金方能保釋。GRS在這次考察旅程的航程中遭到騎劫，如何獲得賠償，仍未有定案。紅寶石價格破世界記錄 我們得知，於6月份，香港珠寶首飾展覽會中，一名商人以一百萬美元售出一顆閃爍動人的7卡紅寶石(Didy) (圖14)。這些紅寶石每顆都是大自然瑰寶，實實在在打破了記錄。GRS在交易中是率先在礦場內已見證寶石開採活動的唯一一家公司。

## GRS新聞發佈，10月22日

(<http://www.gemresearch.ch/video/Didy6.htm>)

GRS於9月份在香港珠寶首飾展覽會中舉行名為「破世界記錄鴿血紅寶石新發現」的研討會，會上公布多項新發現。(見www.jewellerynewsasia.com – 關鍵字：GRS)

## 投資者獲取採礦權， 10月30日

以下資料來自寶石市場：一名主要投資者(GF)已取得山谷較高位置的採礦權，而一家由非馬達加斯加人參與的私人投資集團則取得山谷較低位置的採礦權。雙方均聘請來自Didy的當地人士於礦場工作。

投資集團現時在森林中聘有至少兩名代理監管營運。由於一顆128卡的藍寶石原石從這兩個礦區以外找到並送往GRS作研究，因此於這兩個礦區以外進行額外採礦。產地為Didy的寶石亦再次送交實驗室作檢測。



圖23.一套來自馬達加斯加Didy的藍寶石，介乎5至超過10卡，當中有只會產自斯里蘭卡、緬甸及馬達加斯加Ilakaka的典型GRS一類「皇家藍寶石」。(照片：W.Bieri.© GRS)



圖24. Peretti使用攜帶便攜式顯微鏡目測Ambatondrazaka商人帶來的眾多紅寶石及藍寶石。因這些寶石具備鈦鐵、鋯石簇、藍色帶狀分布，但並無絹絲，透過顯微鏡能輕易將這些寶石從所有其他地區的紅寶石中區分出來，即使於坦桑尼亞Winza的相似寶石亦能區分。對於含有大量負晶體及二級液體特徵、單獨鋯石、黑色鈦鐵簇、導向韭閃石針狀物以及一般缺乏絹絲的藍寶石而言亦是如此。(文獻.2)

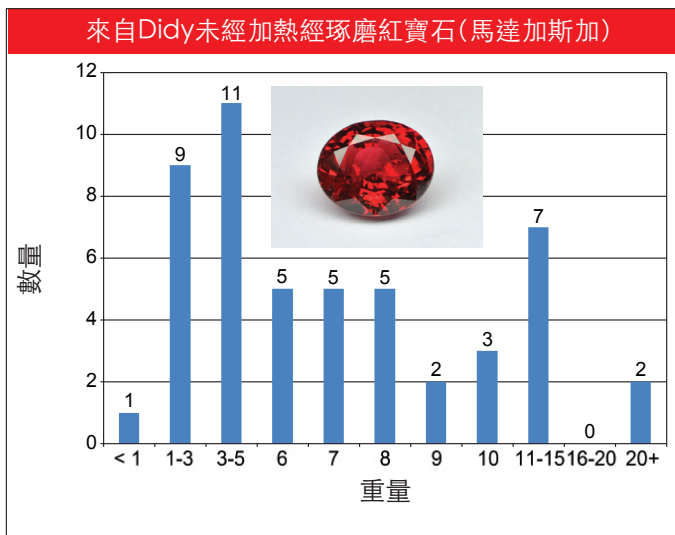


圖25. GRS於發現紅寶石之後3個月對25顆來自馬達加斯加Didy的紅寶石進行測試所得出的統計數字。統計數字顯示，只需一段短時間，便發掘出兩顆超過20卡的瑰麗紅寶石。這些大顆紅寶石通常為緬甸Mogok等大型礦場花數十年開採得來的優質副產品。GRS統計。

文獻1. Adolf Peretti、Francesca Peretti、Anong Kanpraphai、Willy Bieri、Kathrin Hametner及Detlef Günther。發現溫莎紅寶石(Winza Rubies Identified)。收錄於Contributions to Gemology (2008年版) 第7至97頁。

文獻2. Adolf Peretti、Willy Bieri、Kathrin Hametner、Lawrence Hahn及Detlef Günther (2013年)。來自Didy (馬達加斯加) 破世界記錄的紅寶石及藍寶石以及來自Kataragama (斯里蘭卡) 的全新藍寶石礦 (World-record rubies and sapphires from Didy (Madagascar) and the new sapphire mines from Kataragama (Sri Lanka))。地積學與寶石學考察報告 (Expedition Report, Geology and Gemology)。收錄於Contributions to Gemology第12號，印刷本。

文獻3. Carte Métallogénique et de Prédiction des Gisements, Métaux de Base et Métaux Précieux, Feuille No 6-Toamasina (2008年) (J. Ramarolahy, D. Rakotomanana, B. Moine, E. Ortega, L. Chevallier, F. Hartzler, G. S. de Kock, S. W. Strauss et, A. F. Randriamanantenasoa, J. Naden, L. Noakes, Editée par : 英國地質調查局 (British Geological Survey) Keyworth, 諾丁漢, 英國) MINISTÈRE DE L' ÉNERGIE ET DES MINES Projet de Gouvernance des Ressources Minérales (PGRM).

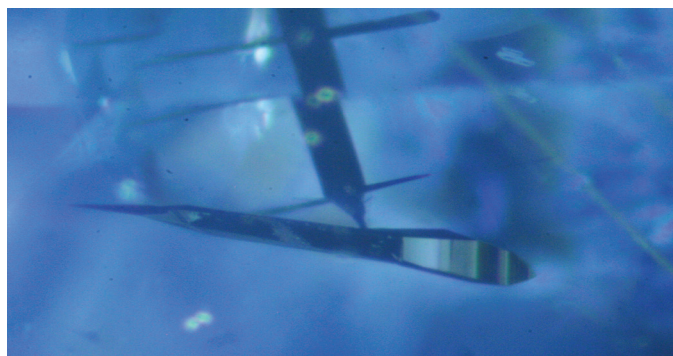


圖 26A.於非洲馬達加斯加戴迪(Didy)出產的藍寶石內,可見 大型的冰鋤狀錳鉍鈮礦物內含物。此發現證實了藍寶石的形成與 偉晶岩鉍鈮礦床有着密切關係。

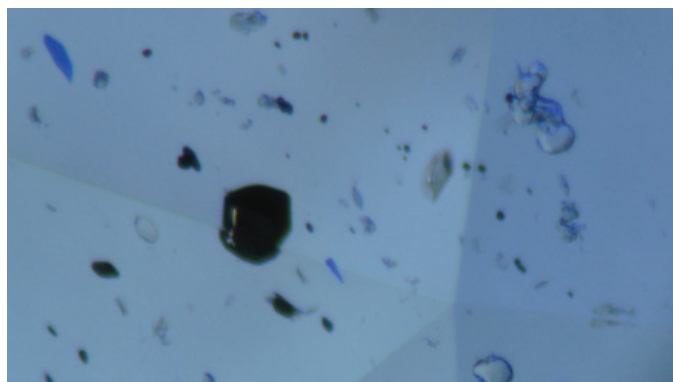


圖26B.於一顆超過5卡的Didy藍寶石中發現含有雲母、鈦鐵及鋯石簇 (GRS收藏)。這些礦物通常可於礦場的閃石—片麻岩層中找到。鈦鐵經 GRS於2012年7月以SEM-EDS分析獲得確認 (瑞士University Fribourg地球科學系SEM—實驗室 M.Meier)。

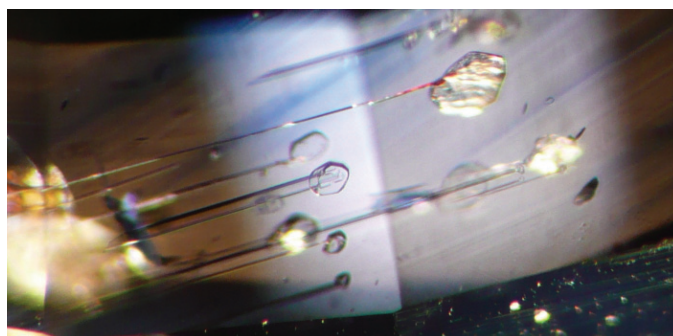


圖26C.在液體內含物空間長出非閃石針狀物, 並可定向生長, 滲透整顆藍寶石。這是作者之一 (AP)首次目睹藍寶石內部的現象, 顯示藍寶石在劇烈熱液狀態中形成。這顆藍寶石亦呈現顏色帶狀分布, 帶狀分布的終止情況並無規律。一如來自馬達加斯加的其他藍寶石, 這顆寶石並無呈現此奶白色部分。

文獻4. Edward Gübelin and Adolf Peretti (1997年)：產自馬達加斯加東南面Adranondambo礦區的藍寶石 (Sapphires from Adranondambo mine in SE Madagascar)：交代硅卡岩形成的憑證 (evidence for metasomatic skarn formation)。寶石學期刊 (Journal of Gemmology) 第25卷第7號第453至470頁。

文獻5. 亞洲珠寶 – 生活秀 (Jewellery News Asia – Show Daily) 2012年9月24日，第10頁。

GRS謹此向以下各方致謝：Y. Group讓我們發現Didy，並提供現場基建及款待；Tom Cushman策劃取得政府及當地通關批文，並安排交通及整理數據；馬達加斯加政府及Didy市長發出通關批文並提供當地支援；Gem Paradise及朋友資料提供；所有當地礦工；Assist Aviation；Ghambi；Diana Jarrett；另外特別鳴謝努力不懈的搬運工人以及拯救我們脫險的Eugene。最後同樣重要的，是GRS團隊，在實驗室面對繁重工作時緊守崗位，令人敬佩。



圖26D.來自馬達加斯加Didy的經琢磨紅寶石內發現折疊羽狀斑疵。這種羽狀斑疵一般預期在藍寶石出現，而紅寶石則並不會有此斑疵。（插圖：W.Bieri & A.Peretti, © GRS）

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# World of Magnificent Spinel - Provenance and Identification

**By Dr. Adolf Peretti & Prof. Detlef Günther and co-authors**  
**Book Review by Bryan Pavlik, FGG**

The most comprehensive provenance study concentrates on spinels from Burma, and is based on 3 separate field trips to Mogok with extensive field work and a total duration of 3 weeks. A map describes the occurrence of fancy and vivid coloured spinels on the 30 km long stretch between Eastern and Western Mogok. The map also contains the occurrence of other gem- and collector stone varieties such as of rubies, painite, johachidolite, jeremejevite etc.. A total of 25 different gems occur in the valley of Mogok. Such a detailed map has so far not been published in the gemmological literature available. Based on this detailed map, the authors continue to analyse the market place in Mogok in a very unique way.

They mapped the major market places over the entire Mogok valley and compared the flow of gems from the mines to local markets. Peretti graphically visualised this by the means of a flow chart showing how Burmese spinels are transported to different markets. Then the authors analyze the movement pattern of the stones and describe the dangers and chances when buying spinel at the source. With a series of case studies it is shown how and why the origin of spinels may be intentionally misrepresented in the Mogok valley by the miners. These mechanisms are shown in 9 different case studies. For example, a spinel may not be sold in Mogok town at first, but later for a higher price near



**Fig. 1: A series of vibrant pink to pinkish-red colored spinels from Mahenge in Tanzania. Picture by Yavorskyy.**



the mine edging on the illusion of source proximity. Finally, the spinel fetched a higher price at the mine than at the major market in Mogok where it had been shown initially. The opening hours of the different markets do support multiple presentations of a gem in different scenarios. The prices that have been paid for ruby, spinel, sapphire, apatite, quartz, topaz and collector gems over the years 2002-2007 have also been analyzed. The market study shows that the dramatic price increases of spinels followed the general trend of price increases of rubies and sapphires. In the following, the book describes the other



**Fig. 2: Market in the Mogok valley near Kyat Pyin. While many local markets are specialized in a particular gem, this market offers a large variety of gems including rubies, sapphires, spinels, collector stones and rough in the range of approx. 100 to 2000 US Dollar per piece or lot (year 2007). Copyright GRS.**

spinel sources with exclusive mining pictures, never seen before geological maps and some very dramatic travel reports. Most interesting is the travel report on Tajikistan where the expedition was entirely conducted on bicycles (The bicycle trip started from Switzerland and ended up in Thailand). A graphic description in the detailed report highlights a scene in the Pamir Mountains where a rocket propelled grenade was shot over the shoulder of the visitor to impress and to underline the demand for the payment of a passage tax.

A large chunk of the book is dedicated to the detailed analyses of the internal world of spinel inclusions.

A collection of typical inclusions is presented for every single spinel occurrence discovered so far. How can a spinel be separated from Vietnam and its counterparts in Tajikistan based on inclusions? For this type of questions, the spinel inclusion compilation in this book contains the best inclusion selection chosen from over 10 000 of the finest photos from Peretti's inclusions library.

In the last quarter of the book, the attention is turned to the advanced testing of spinels. The authors have gone to the extent to analyze all different spinel colour variations sorted by origin with today's most-sophisticated high-tech machines. Approx. 500 chemical analyses by LA-ICP-MS for 40 different elements were conducted. Special attention was given on the concentrations of light weighted elements such lithium, beryllium as well as other element such as cobalt, chromium, vanadium, titanium, gallium etc. The analysis is differentiated into spinels from different



**Fig. 3: One of author (AP) interviews the mine owner and some of his mining engineers directly at the Pingu Town mine in Western-Mogok. Crucial information about mining procedures, geology and mineral occurrences are carefully noted in one of the GRS field books. This information is used to compile the market interactions in the Mogok valley. Photo by Anong Kanpraphai. Copyright GRS.**

origins and their occurring colours as well as the synthetic counterparts currently available on the market today. The following questions can be answered by this type of analysis: Can spinels of different origins be separated by chemical analysis? How much cobalt concentrations are present in spinels from Vietnam? Are there "Cobalt Spinel" from different origins and how big are their cobalt concentrations? Can synthetic spinels be distinguished by

the light element contents such as lithium and beryllium? This part will definitely be carefully noticed by and was intentionally separated from the main text to be studied by the more scientifically interested reader. This enables the non-scientific reader to enjoy the other parts without being troubled too much by science jargon.

When it comes to the interpretation of the formation of spinel in its parent rock, the authors have chosen a very unique way. They analyzed the inclusions in spinel by LA-ICP-MS and focussed on the analyses of Rare Earth Element concentrations in apatite. It must be most interesting for the genesis of spinels in general and will definitely be noticed by the scientific community, once they will get aware of this very surprising research contribution.

The book goes on with the identification of synthetic spinels against the natural counter parts by light elements beryllium and lithium concentrations and of course covers the important issue of heat-treatment of spinels. For this purpose, the authors have built up a replica of the heat-treatment technique used in the Mogok valley and conducted their own heat-treatments on a variety of different spinels by colours and origins; this took place right in Mogok itself. It is then shown what type of spinels can be heated for colour enhancement and which spinels are not suitable for colour enhancement by heat-treatment. The conclusion of the analyses results in the first documentation of colour-changes in spinel by heat-treatment (the discovery was made public in January 2011 by one of the authors during the Tucson GILC-meeting).

Finally, the research documentation in the book proves that heat-treatment changes the crystal structure of spinel. The normal spinel structure is transformed into inverse spinel structure by the means of heat-treatment. A very sophisticated high-tech analysis was necessary using a specialized X-ray technique to unravel this structural transformation of spinel through heat-treatment. The high-tech research is then used to evaluate the differences of Raman spectra between heated and unheated spinels and discusses how this test can be used with an inexpensive Raman spectrometer available in the market.

As another novelty, the book reports on the first Cobalt-diffusion treated natural spinel and shows how it was discovered and analyzed.

The book closes by demonstrating what type of spinels made it into the prestigious international auctions. For this analysis the focus was set on GRS certified spinels that appeared in recent and previous auction catalogues. The most interesting information for dealers is the statistics about the sizes and colours of spinels. This type of information can only be gained by decades of every day work in a gemmological laboratory, testing stones for many different parties. With over 300 pages the book is the largest volume so far of "Contributions to Gemology". It is presented in a richly illustrated hard cover copy. This book is, as the principle authors explain, the summary of almost 2 decades of research collected during practical work in a thriving gemmological laboratory and expeditions to numerous different mines.



Fig. 4: Statistics of certified spinels from various origins sorted by color and size, as tested in the years between 2000-2009. The majority of gems are below 20cts and largest spinels over 100ct were of violet color. The largest blue spinels are 20ct in size. Copyright GRS.

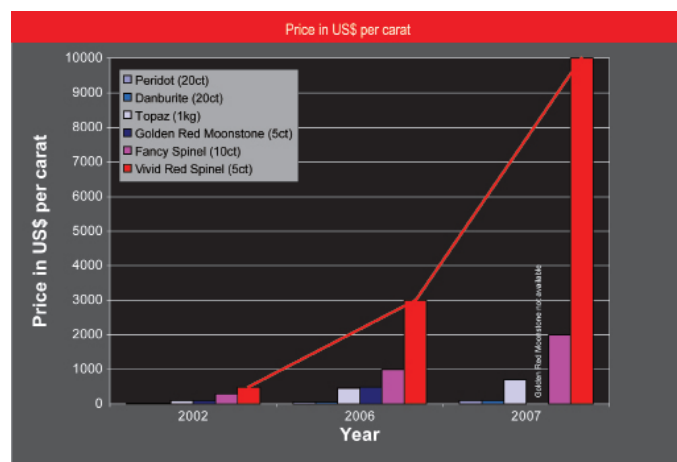


Fig. 5: Price evolution of collector gems and spinels in the valley of Mogok between 2002 and 2007. Note the extremely strong increase of vivid red spinels within a period of 5 years (20-fold). It mirrors the price evolution of pigeon's blood rubies (not shown on the graph). Copyright GRS.

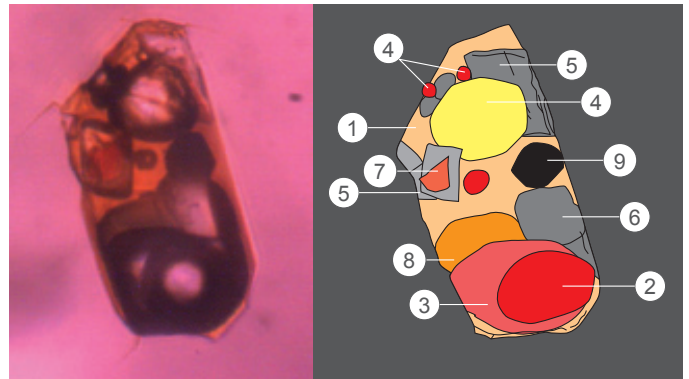


*Fig. 6: A rare piece of spinel in matrix from Tadjikistan. The spinel of 1.5cm length is embedded in a white forsterite vein and a large pyrrhotite crystal. Copyright GRS.*

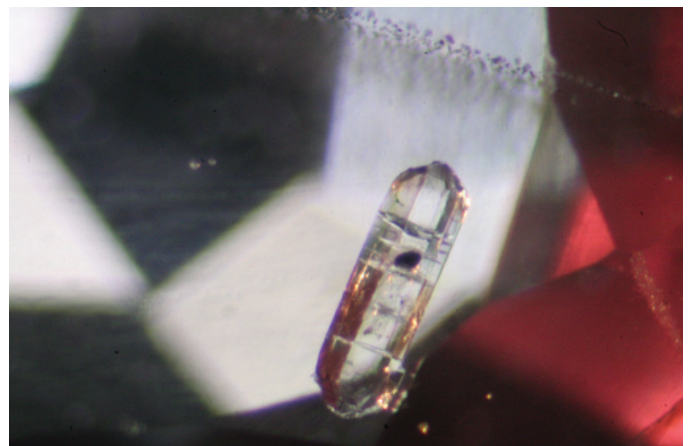
It also includes a broad collaboration and expertise of other laboratory and research scientists. Through these cooperations within this expert group a substantial contribution, especially concerning high tech analyses of spinels makes this book the first standard literature on this subject. In summary this outstanding contribution to the gemstone industry is a true commitment to excellence in gemmological research and definitely a must for every serious library.

**World of Magnificent Spinel - Provenance and Identification**

**By Dr. Adolf Peretti & Prof. Detlef Günther**  
 With contributions by Ngwe Lin Tun, Anong Kanpraphai, Kathrin Hametner and Willy Bieri  
 Contributions to Gemology, No. 11, 300 pages  
 ISBN 978-3-9523867-2-9  
 Price 150 US Dollars



*Fig. 7: Multiphase inclusion in a spinel from Mansin (East-Mogok). Liquid: 1 Yellowish liquid, Gas: 2 Dark gas bubble, 3 Honey-colored gas bubble, 4 Grayish-yellow gas bubble and Solid: 5 Monocline light grey solid, 6 Rounded light grey solid, 7 Reddish platelets, with corners, 8 Dark brown solids, off-round and 9 black solids, hexagonal. Sketch and Photo by J. Mullis. Copyright GRS.*



*Fig. 8: Prismatic apatite inclusions are present adjacent to an opaque cubic black inclusion (interpreted as uraninite) in this faceted spinel from Kyauksin (Burma, Myanmar). Copyright GRS. All pictures are from the book.*

# 奇妙的尖晶石

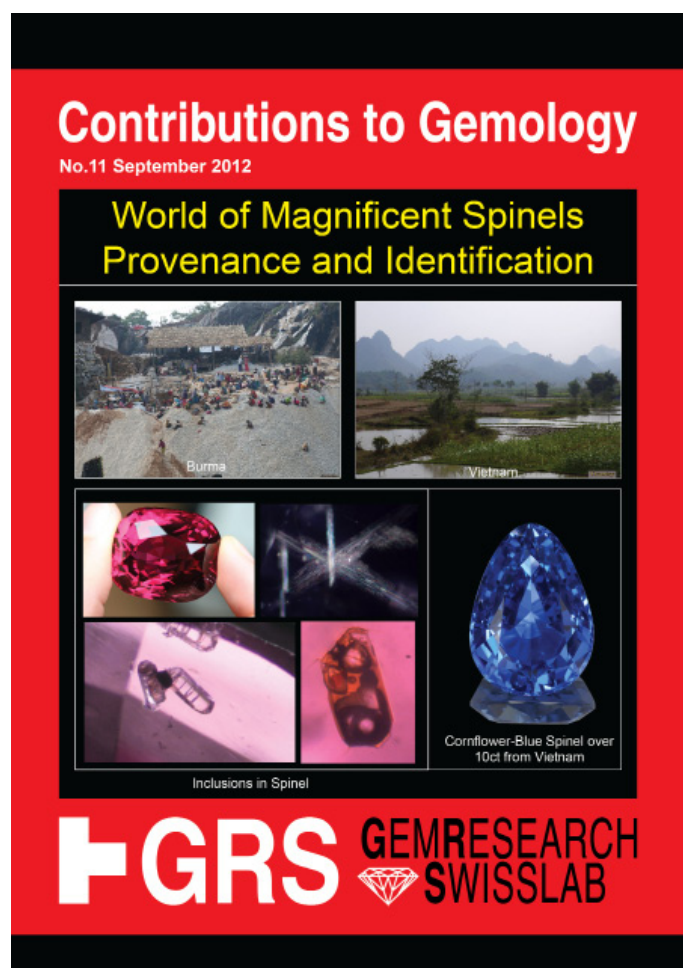
## ——产地与鑑定

Adolf Peretti 博士、Detlef Günther 教授等著  
Bryan Pavlik (FGG) 评

本书乃历来最全面的缅甸尖晶石产地研究，基于三星期期间、三次于莫谷详细实地考察的结果。莫谷流域一带共发现25种不同的宝石，而书内一张地图标示了莫谷东部至西部30公里范围内发现彩色及达到鲜艳级数的尖晶石矿藏所在，同时亦标出发现红宝石、铝硼钙石、水氟硼石、硼铝石等宝石级及收藏级宝石的地理位置。该地图之详细，于宝石学文献中前所未见。依据此详细之地图，几位作者以独特的方式深入分析莫谷的宝石市场——他们于地图上标示了整个莫谷流域内的各个主要宝石市场，并比较宝石从矿场运送至当地市场的流程。Peretti博士更以作业图的方式，清晰地显示出缅甸尖晶石如何被运送到不同的市场。作者继而分析宝石之移动模式，并阐释于产地直接购买尖晶石的风险与机率。透过9个不同的个案研究，作者解释了莫谷流域的矿工如何及为何故意错误描述尖晶石的来源。



图1. 坦桑尼亚马亨格出产的数颗粉红及浅红色尖晶石。摄：Yavorsky



譬如说，一名莫谷市的尖晶石商人，可能并不在莫谷市主要市场里出售尖晶石，反而于较接近矿场的市场，利用「接近产地」的错觉，以较高的价钱出售该石。因此，矿场附近市场的尖晶石价格，反而比其来源处（莫谷市主要市场）的高。此外，市场营业时间各有不同，一颗宝石于不同市场内便会有不同的描述。另一方面，作者又分析了2002至2007年间，红





**图2. 莫谷流域近贾特宾的市场。与当地其它专营特定品种宝石的市场不同，此市场出售品种多样的宝石，包括红宝石、蓝宝石、尖晶石及收藏级宝石，每颗或每批次的价格约为100至2,000美元不等（2007年价格）。GRS版权所有。**

宝石、尖晶石、蓝宝石、磷灰石、石英、黄晶及收藏级宝石的价格。市场研究的结果显示，尖晶石的价格随着红宝石及蓝宝石价格的升势而大幅飙升。下文将探究尖晶石的其它来源，并附上独家探矿图片、从未曝光的地图，以及一些非常引人注目的旅程报告。其中最有趣的，可谓塔吉克斯坦之旅，因为考察队全程以自行车代步（此自行车之旅于瑞士开始，至泰国结束）；书中更以插图详细描述旅程中险象横生的一幕：当地人向访客近距离发射火箭推进榴弹，以炫耀军力并勒索过路费，榴弹跟考察队成员真正「擦肩而过」。

本书以颇大篇幅详细分析了尖晶石内含的夹杂物。

迄今为止，每一颗开采出来的尖晶石均含有某几种典型的夹杂物。专家如何利用夹杂物来鉴别一颗尖晶石是来自越南还是塔吉克斯坦？本书将有分晓。Peretti博士从他超过10,000张的夹杂物图片库中，挑选及辑录了历来最齐全、素质最高的尖晶石夹杂物图片。

于书末章节，焦点转到先进的尖晶石测试



**图3. 作者之一（Adolf Peretti博士）于莫谷西部平古镇矿场内，亲自访问矿主及探矿工程师。探矿工序、地质学及出产矿种的关键信息，将详细记载于GRS另一本实地考察书中，以揭示莫谷流域的市场互动。摄：Anong Kanpraphai。GRS版权所有。**

方法之上。作者利用当今最精密的高科技仪器「激光剥蚀感应耦合电浆质谱仪」（LA-ICP-MS），对40种元素进行了近500次化学解析，以分析不同产地的尖晶石颜色差异。

本书其中一章特别研究尖晶石中轻元素如锂和铍，以及钴、铬、钒、钛、镓等其他

元素的浓度，藉此鉴别不同产地的尖晶石的颜色，同时比较这些天然石与现时市面上的人造尖晶石的颜色差别。这些颜色差别可解答以下的问题：化学分析可否区分出不同产地的尖晶石？越南尖晶石的钴浓度有多少？有哪几个地区出产「钴尖晶石」？这些「钴尖晶石」的钴浓度是多少？可否从锂或铍等轻元素的含量，鉴别出哪些是人造尖晶石？作者特意将此部分内容从主文中分拆出来，作为独立的章节，一来可吸引对科学较有兴趣的读者细读，二来亦方便普通读者阅读主文，不至于被此章节的大量科学术语碍了读兴。

作者选择了一个非常独特的方式，来阐释尖晶石如何于母岩内形成：他们利用激光剥蚀感应耦合电浆质谱仪解析尖晶石内的夹杂物，并集中分析磷灰石内的稀土元素的浓度。研究之结果令人十分意外，更与尖晶石的起源息息相关，必定引起科学界的注目。

本书继而解释如何以轻元素铍及锂的浓度来分辨人造尖晶石与天然石，当然更少不了尖晶石热处理这个重要议题。为此，身在莫谷的作者，特意複製了一个莫谷流域

常用的热处理模型，实地热处理了各种不同颜色、不同产地的尖晶石，以此阐明哪些尖晶石适合用热处理来改善色泽而哪些不适合。这是史上首次有文献记载热处理尖晶石的颜色改变（其中一位作者于2011年1月美国图森市「宝石业界及实验室会议」中，首次将分析结果公诸于世）。

最后，研究结果证实，热处理可将尖晶石正常的晶体结构变为相反，但这个转变必须以独特的X射线技术方能测辨得到。作者继而以此高科技的研究来鉴定经热处理前后尖晶石的拉曼光谱的差异，并讨论如何以市面上的普通廉价拉曼光谱仪进行这个测试。

本书的另一创举，是首次报告天然尖晶石经钴扩散处理的发现与分析。

最后，书中罗列了哪几种尖晶石可跻身国际拍卖会。作者将分析的焦点放于近期及过往拍卖会小册子内找到的GRS认证尖晶石。相信书内关于尖晶石大小及颜色的数据，是宝石代理们最感兴趣的信息。这些数据采自数十年来宝石实验室每天为不同团体进行的宝石鉴定，可谓得来不易。

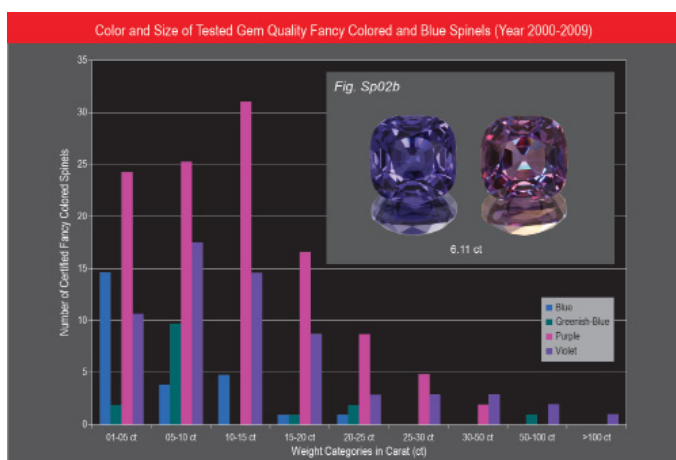


图4. 作者于2000至2009年依照颜色及体积鉴定不同产地的已认证尖晶石的数据。大部分宝石的重量少于20克拉；最重的超过100克拉，且全部均为紫尖晶石。最大的蓝尖晶石重20克拉。GRS版权所有。

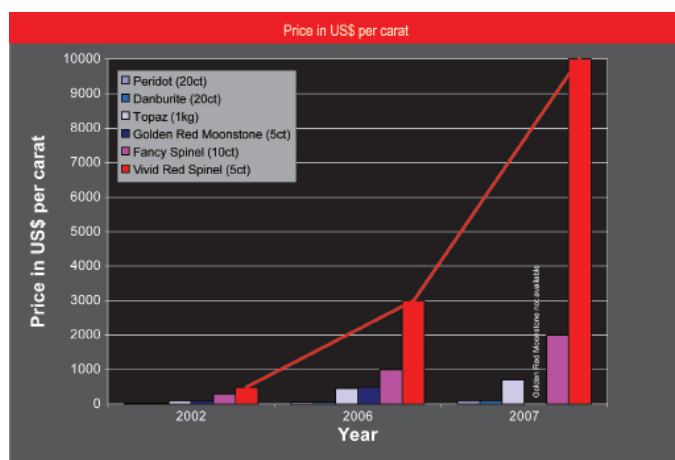


图5. 莫谷流域收藏级宝石及尖晶石于2002至2007年间的价格升幅。注意：艳红色尖晶石的价格于短短5年内飙升多达20倍，正好呼应鸽血红宝石（非标示于表中）的价格升势。GRS版权所有。



图6. 一颗产于塔吉克斯坦母岩的尖晶石。此稀有的尖晶石藏于镁橄榄石矿脉及一巨型磁黄铁矿晶体之中。GRS版权所有。

此书属精装本，长逾300页，插图丰富，是《Contributions to Gemology》丛中至今篇幅最长的一本。根据主要作者的解释，此书总结了他们近20年来于一家著名宝石学实验室及不同矿场实地考察的实验及研究成果。

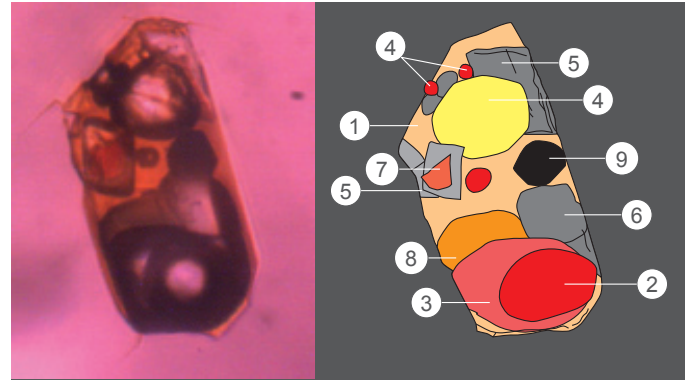


图7. 一颗产自曼辛（莫谷东部）的尖晶石内的多相夹杂物。液体：1 偏黄液体，气体：2 深色气泡、3 蜜糖色气泡、4 灰黄色气泡及固体：5 单斜浅灰色固体、6 圆形浅灰色固体、7 带红小片，带角、8 深棕色固体，偏圆及9 黑色固体，六角形。略图及摄影：J. Mullis。GRS版权所有。

本次考察，作者与多家实验室及多位研究科学家合作，汇聚各界的专业知识，令此书成为尖晶石高科技分析的最佳文献。这群专业人士为宝石学带来无可比拟的贡献，实现了他们对宝石学研究精益求精的承诺。总的来说，此书绝对是每一家认真的图书馆必备的著作。

**奇妙的尖晶石——产地与鑑定**

作者 *Adolf Peretti* 博士 *Detlef Günther* 教授

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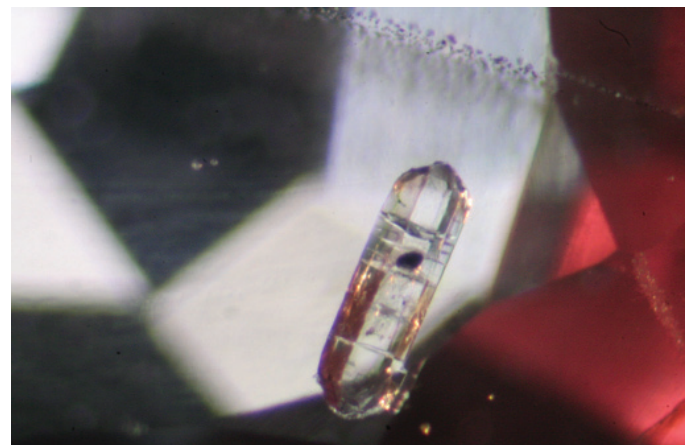


图8. 这颗产自缅甸奇奥特什姆伊奥的多面体尖晶石，含有棱柱形磷灰石夹杂物，并连接着一颗黑色的不透明立方体夹杂物（书中称作「沥青矿」）。GRS版权所有。所有图片取自书本。

# 奇妙的尖晶石

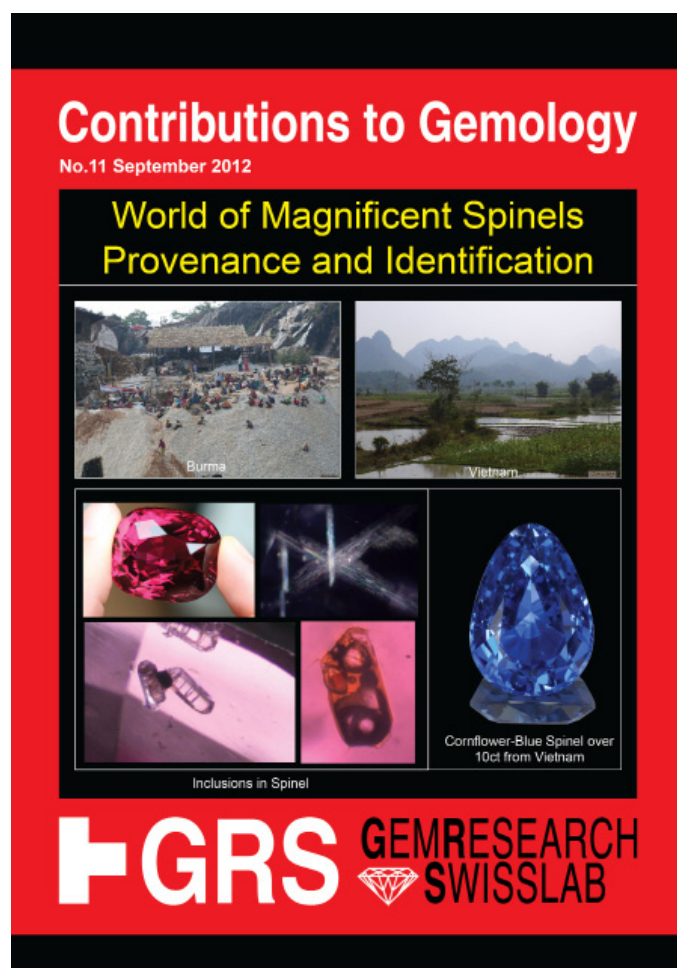
## —產地與鑑定

Adolf Peretti 博士、Detlef Günther 教授等著  
Bryan Pavlik (FGG) 評

本書乃歷來最全面的緬甸尖晶石產地研究，基於三星期期間、三次於莫谷詳細實地考察的結果。莫谷流域一帶共發現25種不同的寶石，而書內一張地圖標示了莫谷東部至西部30公里範圍內發現彩色及達到鮮艷級數的尖晶石礦藏所在，同時亦標出發現紅寶石、鋁硼鈣石、水氟硼石、硼鋁石等寶石級及收藏級寶石的地理位置。該地圖之詳細，於寶石學文獻中前所未見。依據此詳細之地圖，幾位作者以獨特的方式深入分析莫谷的寶石市場——他們於地圖上標示了整個莫谷流域內的各個主要寶石市場，並比較寶石由礦場運送至當地市場的流程。Peretti博士更以作業圖的方式，清晰地顯示出緬甸尖晶石如何被運送到不同的市場。作者繼而分析寶石之移動模式，並闡釋於產地直接購買尖晶石的風險與機率。透過9個不同的個案研究，作者解釋了莫谷流域的礦工如何及為何故意錯誤描述尖晶石的來源。



圖1. 坦桑尼亞馬亨格出產的數顆粉紅及淺紅色尖晶石。攝：Yavorsky



譬如說，一名莫谷市的尖晶石商人，可能並不在莫谷市主要市場裏出售尖晶石，反而於較接近礦場的市場，利用「接近產地」的錯覺，以較高的價錢出售該石。因此，礦場附近市場的尖晶石價格，反而比其來源處（莫谷市主要市場）的高。此外，市場營業時間各有不同，一顆寶石於不同市場內便會有不同的描述。另一方面，作者又分析了2002至2007年間，紅



**圖2. 莫谷流域近賈特賓的市場。與當地其他專營特定品種寶石的市場不同，此市場出售品種多樣的寶石，包括紅寶石、藍寶石、尖晶石及收藏級寶石，每顆或每批次的價格約為100至2,000美元不等（2007年價格）。GRS版權所有。**

寶石、尖晶石、藍寶石、磷灰石、石英、黃晶及收藏級寶石的價格。市場研究的結果顯示，尖晶石的價格隨着紅寶石及藍寶石價格的升勢而大幅飆升。下文將探究尖晶石的其他來源，並附上獨家採礦圖片、從未曝光的地圖，以及一些非常引人注目的旅程報告。其中，最有趣的可謂塔吉克之旅，因為考察隊全程以自行車代步（此自行車之旅於瑞士開始，至泰國結束）；書中更以插圖詳細描述旅程中險象橫生的一幕：當地人向訪客近距離發射火箭推進榴彈，以炫耀軍力並勒索過路費，榴彈跟考察隊成員真正「擦肩而過」。

本書以頗大篇幅詳細分析了尖晶石的內含物。

迄今為止，每一顆開採出來的尖晶石均含有某幾種典型的內含物。專家如何利用內含物來鑑辨一顆尖晶石是來自越南還是塔吉克？本書將有分曉。Peretti博士從他超過10,000張的內含物圖片庫中，挑選及輯錄了歷來最齊全、質素最高的尖晶石內含物圖片。

於書末章節，焦點轉到先進的尖晶石測試



**圖3. 作者之一（Adolf Peretti博士）於莫谷西部平古鎮礦場內，親自訪問礦主及採礦工程師。關於採礦工序、地質學及出產礦種的關鍵信息，將詳細記載於GRS另一本實地考察書中，以揭示莫谷流域的市場互動。攝：Anong Kanraphai。GRS版權所有。**

方法之上。作者利用當今最精密的高科技儀器「雷射剝蝕感應耦合電漿質譜儀」（LA- ICP-MS），對40種元素進行近500次化學解析，以分析不同產地的尖晶石的顏色差異。

本書其中一章特別研究尖晶石中輕元素如鋰和鈹，以及鈷、鉻、釩、鈦、鎳等其他

元素的濃度，藉此鑑別不同產地的尖晶石的顏色，同時比較這些天然石與現時市面上的同類人造尖晶石的顏色差別。這些顏色差別可解答以下的問題：化學分析可否區分出不同產地的尖晶石？越南尖晶石的鈷濃度有多少？有哪幾個地區出產「鈷尖晶石」？這些「鈷尖晶石」的鈷濃度是多少？可否從鋰或鉍等輕元素的含量，鑑辨出哪些是人造尖晶石？作者特意將此部分從主文中分拆出來，作為獨立的章節，一來可吸引對科學較有興趣的讀者細讀，二來亦方便普通讀者閱讀主文，不至於被此章節的大量科學術語礙了讀興。

作者選擇了一個非常獨特的方式，來闡釋尖晶石如何於母岩內形成：他們利用「雷射剝蝕感應耦合電漿質譜儀」解析尖晶石的內含物，並集中分析磷灰石內的稀土元素的濃度。研究之結果令人十分意外，更與尖晶石的起源息息相關，定必引起科學界的注目。

本書繼而解釋如何以輕元素鉍及鋰的濃度來分辨人造尖晶石與天然石，當然更少不了尖晶石熱處理這個重要議題。為此，身在莫谷的作者，特意複製了一個莫谷流域

常用的熱處理模型，實地熱處理了各種不同顏色、不同產地的尖晶石，以此闡明哪些尖晶石適合用熱處理來改善色澤而哪些不適合。這是史上首次有文獻記載熱處理尖晶石的顏色改變（其中一位作者於2011年1月美國圖森市「寶石業界及實驗室會議」中，首次將分析結果公諸於世）。

最後，研究結果證實，熱處理可將尖晶石正常的晶體結構變為相反，但這個轉變必須以獨特的X光技術方能辨測得到。作者繼而以此高科技的研究來鑑定經熱處理前後尖晶石的拉曼光譜的差異，並討論如何以市面上的普通廉價拉曼光譜儀進行這個測試。

本書的另一創舉，是首次報告天然尖晶石經鈷擴散處理的發現與分析。

最後，書中羅列了哪幾種尖晶石可躋身國際拍賣會。作者將分析的焦點放於近期及過往拍賣會小冊子內找到的GRS認證尖晶石。相信書內關於尖晶石大小及顏色的數據，是寶石代理們最感興趣的資料。這些數據採自數十年來寶石實驗室每天為不同團體進行的寶石鑑定，可謂得來不易。

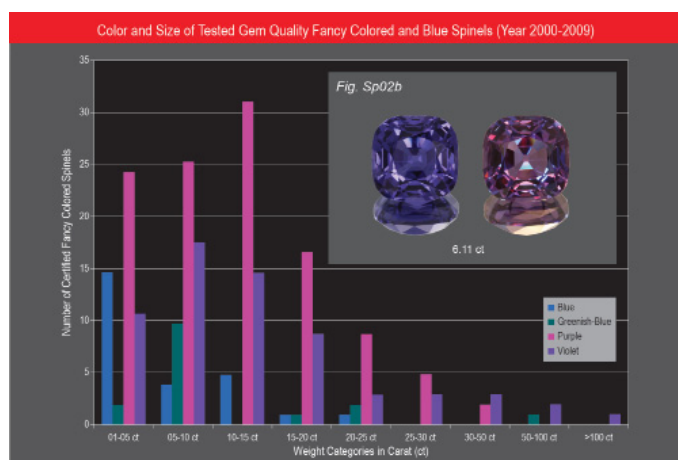


圖4. 作者於2000至2009年依照顏色及體積鑑定不同產地的已認證尖晶石的數據。大部分寶石的重量少於20克拉；最重的超過100克拉，且全部均為紫尖晶石。最大的藍尖晶石重20克拉。GRS版權所有。

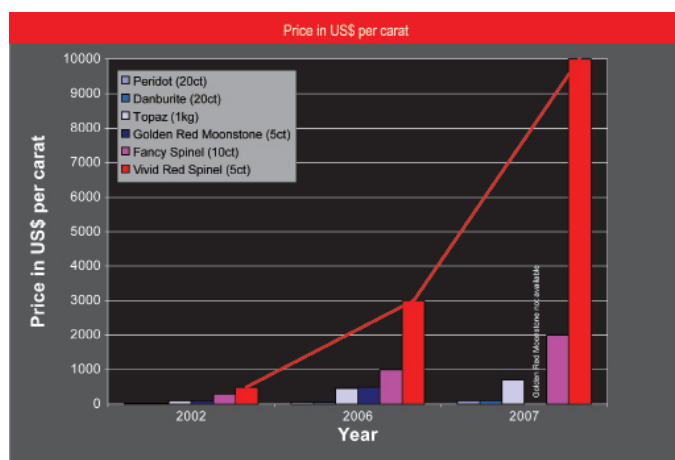


圖5. 莫谷流域收藏級寶石及尖晶石於2002至2007年間的價格升幅。注意：艷紅色尖晶石的價格於短短5年內飆升多達20倍，正好呼應鴿血紅色紅寶石（非標示於表中）的價格升勢。GRS版權所有。



圖6. 一顆產於塔吉克斯坦母岩的尖晶石。此稀有的尖晶石藏於鎂橄欖石礦脈及一巨型磁黃鐵礦晶體之中。GRS版權所有。

此書屬精裝本，長逾300頁，插圖豐富，是《Contributions to Gemology》叢書中至今篇幅最長的一本書。根據主要作者的解釋，此書總結了他們近20年來於一家著名寶石學實驗室及不同礦場實地考察的實驗及研究成果。

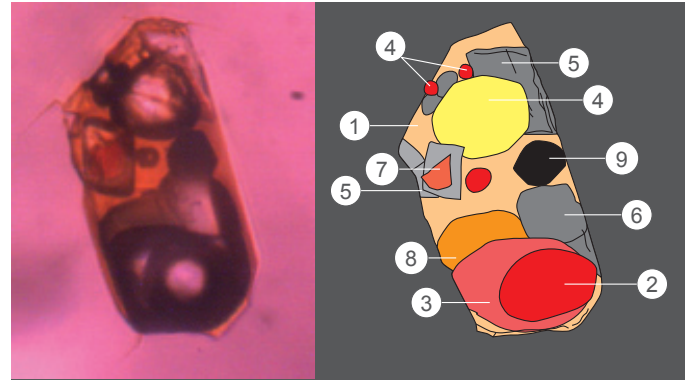


圖7. 一顆產自曼辛（莫谷東部）的尖晶石內的多相內含物。液體：1 偏黃液體，氣體：2 深色氣泡、3 蜜糖色氣泡、4 灰黃色氣泡及固體：5 單斜淺灰色固體、6 圓形淺灰色固體、7 帶紅小片，帶角、8 深棕色固體，偏圓及9 黑色固體，六角形。略圖及攝影：J. Mullis。GRS版權所有。

本次考察，作者與多家實驗室及多位研究科學家合作，匯聚各界的專業知識，令此書成為尖晶石高科技分析的最佳文獻。這群專業人士為寶石學帶來無可比擬的貢獻，彰顯了他們對寶石學研究精益求精的熱誠及承諾。總的來說，此書絕對是每一家認真的圖書館必備的著作。

**奇妙的尖晶石——產地與鑑定**

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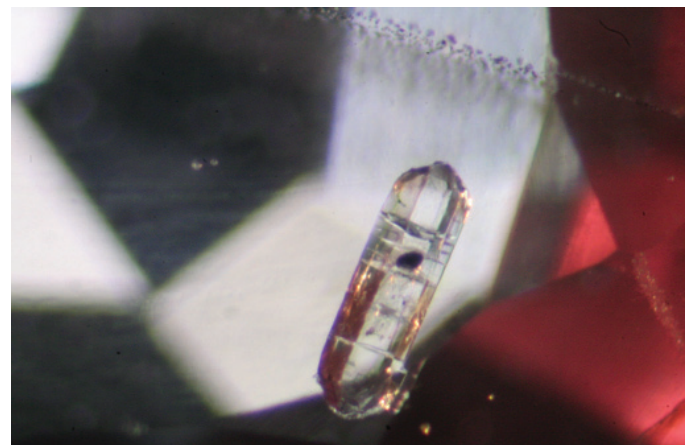


圖8. 這顆產自緬甸奇奧特什姆伊奧的多面體尖晶石，含有棱柱形磷灰石內含物，並連接着一顆黑色的不透明立方體內含物（書中稱作「瀝青鉛礦」）。GRS版權所有。所有圖片取自書本。

# Rubies, Sapphires and Padparadscha from Didy, Madagascar 马达加斯加Didy 矿的红,蓝宝石和帕德玛刚玉

## ROYAL BLUE SAPPHIRES | 皇家蓝蓝宝石



A set of sapphires from Didy ranging from 5 to over 10 ct. with the typical GRS-type "Royal Blue" colors, normally found solely in sapphires from Sri Lanka, Burma and Ilakaka (Madagascar).

## VIVID RED RUBY | 明艳色调红宝石



A gem-quality rough (left) of over 60 ct. from Didy is faceted into an over 26 ct. magnificent ruby (right).

## PADPARADSCHA | 帕德玛刚玉



On the left-hand side is an 85 ct. rough Padparadscha sapphire that is completely clean. Another example of a high-value faceted Padparadscha sapphire of 18 ct. is shown face-up and in profile position. This Padparadscha is loupe clean, has a perfectly mixed orange and pink color, is spared of thermal enhancement and does not show any color-zoning. It is one of the largest faceted magnificent Padparadscha sapphires ever tested by GRS.



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