

Tribute to Terry Leach
by
Phillip Hellman

The Terry Leach Symposium was organised to honour the life and work of Terry. The Organising Committee decreed that contributions detailing his role or his scientific contribution to the aftermath of Bre-X fraud that came to light in 1997 be excluded from the symposium.

This tribute seeks to redress this omission and provides a personal perspective based on a close working relationship with Terry on various projects that commenced with his visit to Busang in April 1997 until his untimely death on 28 February 2007. A focus of the last 10 years of Terry's life was his work on Busang and providing expert evidence in the lengthy trial of John Felderhof. Terry's contributions to the scientific understanding of Busang are included in this tribute.

In my work with Terry I rarely heard him express strong feelings or frustration. He was always circumspect and restrained in his judgements of others. Three incidents stand out.

I recall his disappointment with a particular referee from the international journal *Economic Geology*. Great difficulty was experienced in getting a paper¹ accepted. One referee, by virtue of his own particular views on the role of boiling vs mixing in the generation of epithermal gold-silver deposits, was responsible for the delay of this major contribution to the understanding of gold-copper deposits in the SW Pacific. Terry's frustration with the process of publishing was expressed in typically soft terms. I am sure I would have expressed stronger opinions.

On one occasion Terry was uncharacteristically upset after he had attended a conference in Adelaide where, in one paper, a number of diagrams were presented. These had originated from his work with no acknowledgement. It is a good lesson for us all - it costs nothing to properly acknowledge the work of others. Again, Terry's reaction was restrained considering the blatant plagiarism. He sought no redress.

As Terry testified² during his testimony in the trial of John Felderhof, his support for John resulted in considerable and unreasonable pressure placed on him not to be involved. Terry was not a person who would sacrifice his support for someone he knew to be innocent for the sake of reputation. His willingness to subject himself to the combative environment of cross-examination ran counter to his gentle nature. His position was subsequently completely vindicated. His support for his friend John Felderhof remains as an example of commitment to loyalty and principle rather than sensitivity to the opinion of others.

¹ Corbett, G.J., and Leach, T.M., 1998, Southwest Pacific Rim Gold-Copper Systems : Structure, alteration and mineralization. Special Publication Number 6, Society of Economic Geologists, 236p.

² Ontario Court Of Justice: Her Majesty The Queen against John Bernard Felderhof. Continued trial proceeding, Volume 148, Before The Honourable Justice P. Hryn, on Monday, December 12th, 2005, at Court Room No. 5-1, 361 University Avenue, Toronto, Ontario. pp 69 & 70

The esteem to which Terry was held by many all over the world was typified by the visit of Joe Groia to say good-bye in January 2007 several weeks before Terry's death. It is a long journey from Toronto, Canada to Coromandel in the north island of New Zealand. Joe was John Felderhof's defence lawyer and had worked with Terry since 1997. We were both choking with emotion as we walked down the drive-way, uncertain as to what to say or how to say it.

During the conversation I told Terry that Hellman and Schofield had decided to set up a Terry Leach Scholarship to assist a PhD student with their field work or for overseas study. Despite being in a desperate situation Terry jokingly asked if he could apply.

We then said good bye.

Phillip Hellman

(I have included below some of Terry's published and unpublished work on Busang. This should be of great interest to readers interested in the application of petrology to geological models in mineral exploration and Terry's scientific insights into the Busang fraud.)

Terry and Busang

On 19 March, 1997 Michael de Guzman, Bre-X's Exploration Manager, is widely believed to have died after falling from a helicopter between Samarinda and Busang on the island of Kalimantan, Indonesia. There is still debate as to whether it was murder or suicide.

As a result of the subsequent collapse of Bre-X Minerals Ltd, charges were laid by the Ontario Securities Commission ("OSC") in May 1999. The ensuing trial of Mr John Felderhof, Bre-X's General Manager Exploration, Indonesia has resulted in over 1600 exhibits and 15,000 pages of transcripts. The trial was delayed in April 2001 when the OSC attempted to have the judge removed from the case. This motion was dismissed and an appeal by the OSC was lost. The case restarted in 2004 and the verdict delivered on 31 July 2007 dismissed all charges.

Terry Leach appeared as a fact and expert witness. He appeared in court for four days from Monday 12 until Thursday 15, December 2005. As part of his work on Busang Terry prepared a two volume expert's report consisting of a detailed analysis of various issues relating to the various "red flag" allegations that under-pinned the Ontario Securities Commission's case against John Felderhof, Bre-X's General Manager of Exploration.

The near-300 page report addressed many issues relevant to the evaluation and exploration of epithermal gold-silver deposits. I have included in Appendix 1 the Table of Contents of both volumes in order that an appreciation of the breadth of his scientific work can be appreciated. I have included extracts that relate to the similarity of Kelian with Busang, the conceptual model to explain the alteration system at Busang and the relevance of quartz veining. There are many other areas that Terry addressed that are relevant to minerals exploration and the petrology of hydrothermal activity.

Terry's scientific work on Busang culminated in the presentation of two papers. The first was presented to the Indonesian Mining Association in Yogyakarta in 2001. A version of this is included towards the end of this tribute. The second paper was presented on 2002 in Auckland (see Appendix 2)³.

The conclusions that apply to both of Terry's presentations are quoted below.

"This study of the core samples from Busang has recognized the progressive evolution of a large magmatic-related hydrothermal system that is comparable to that encountered in many similar systems elsewhere in the Pacific region (Leach, 1999).

Early stage porphyry quartz-molybdenite veins formed under hot, saline conditions, and are probably related to the initial exsolution of fluids from a cooling magma. Felsic magmas are typically associated with porphyry-molybdenite systems (Carten et al., 1993). It is therefore postulated that the late stage rhyolite dikes, that have been recognized elsewhere at Busang, are apophyses of a felsic intrusion at depth under the Southeast Zone, and that this intrusion is the likely source of the hydrothermal systems at Busang. Similar late stage rhyolite dikes are encountered at Kelian (van Leeuwen et al, 1990), and are probably genetically related to the gold mineralization in that deposit.

³ I was privileged to present a paper following Terry at the same Auckland conference. At the end of this tribute I have included the abstract of my paper given at the NZ conference to help readers understand the context of Terry's work.

The presence of tourmaline and apatite in the extensive phyllic alteration assemblages in the Southeast Zone indicates that volatile-rich magmatic fluids were channeled over a large area. Similar large phyllic alteration halos have been recognized to be commonly associated with porphyry systems around the Pacific rim (Sillitoe, 2000).

Quartz-adularia veins were deposited during the establishment of a circulating-meteoric-dominated hydrothermal system. Late stage exsolution of metal-bearing brines along the margins of this system, deposited carbonate-base metal veins as these fluids cooled at shallow levels in the Central Zone. There is evidence that there was an outflow of these fluids into the Southeast Zone. This outflow formed extensive late stage carbonate-pyrite-marcasite veins, local base metal-sulphide-rich carbonate veins, and widespread argillic alteration that overprinted onto the earlier porphyry-related assemblages.

As the hydrothermal system continued to wane, there was local deposition of epithermal quartz veins and associated Au-As-Sb mineralization onto the earlier formed vein systems. (Leach, 2001).

Appendix 3 provides some extracts of his Expert Report.



Terry and John Felderhof, Coromandel Peninsula, New Zealand, September 2002

Terry provided expert evidence in the trial of Ontario Securities Commission vs J B Felderhof. John was completely vindicated by Justice Peter Hryn in July, 2007, Toronto, Canada.

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APPENDIX 2

Alteration and Mineralisation in Drillcore from the Busang Prospect, East Kalimantan, Indonesia⁴

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ABSTRACT

Core samples that were collected from the Busang prospect, East Kalimantan, reflect a progressive evolution of a large magmatic-related hydrothermal system that is comparable to that encountered in many similar systems elsewhere in the Pacific region. The initial, localized deposition of porphyry quartz-molybdenite veins took place at high temperatures and salinity at deep levels. This was followed by an extensive phase of phyllic (sericite-quartz-pyrite \pm tourmaline-apatite) wallrock replacement and vein formation. Propylitic (epidote-chlorite-carbonate-quartz) alteration was formed marginal to the phyllic assemblages. These porphyry-related events were centred in the Southeast Zone, and are postulated to be associated with the emplacement of a felsic intrusion at depth.

The early stages of hydrothermal activity were followed by an episode of quartz (\pm adularia) – carbonate – base metal sulphide veining, that was accompanied by argillic (illitic-kaolin clay) wallrock alteration. This event was sulphide-rich in the Central Zone and carbonate-dominated in the Southeast Zone. Gold mineralisation was observed in Central Zone core to be associated with both sulphide, as well as carbonate, deposition.

A final stage of epithermal-style quartz \pm stibnite – realgar veins are, in the Central Zone, locally gold-bearing. The latter two events are interpreted to be associated with the late-stage exsolution of metal-bearing brines from the felsic intrusion that formed the earlier porphyry quartz-molybdenite veins and widespread phyllic-propylitic alteration.

1. INTRODUCTION

This paper is a summary of the results of a petrological study that was carried out on a suite of one hundred and twenty-nine core samples that were collected by the author while on site at the Busang Prospect, East Kalimantan, during April, 1997.

Samples were selected mainly from 10cm long skeleton core that was stored on site, although whole core samples were also collected from three holes that had not yet been sampled for assaying. A suite of forty-seven samples were collected from twenty-three holes that were drilled in the Central Zone, and fifty-three samples were selected from six holes in the Southeast Zone. The remaining twenty-nine samples were selected from Drillhole BDH 5, which was a 980m deep hole drilled under the Southeast Zone.

There has been a considerable amount of factually incorrect information made available over the last four years on the characteristics of the Busang area. It is hoped that this paper will present a sound scientific approach that may help to balance out this lack of basic data.

2. STRUCTURAL SETTING

The Busang prospect is located in East Kalimantan, approximately 200km north of the coastal city of Samarinda. The hydrothermal system at Busang has been localised at the intersection of the NE-trending Kalimantan suture and NW-striking transfer structures. A similar tectonic setting hosts gold mineralisation at the Kelian gold mine approximately 150km to the southwest of Busang, at the Mt. Muro gold mine, as well as other major gold prospects in Kalimantan such as Muyup, Masupa Ria, Miwah and Gunung Mas (van Leeuwen et al, 1990).

A 1km x 500m wide zone of alteration in the Central Zone (CZ) at Busang is thought to have been the focus of dilation of pre-existing EW fractures by dextral movement on the transfer structures. NW-trending alteration in the Southeast Zone (SEZ) extends over a strike length of more than 3km and is postulated also to be related to movement on these transfer structures.

⁴ Presented to Indonesian Mining Conference and Exhibition 2001 - Jakarta

3. GEOLOGICAL SETTING

Alteration and mineralisation at Busang are hosted in a series of polyphasal porphyry intrusions that are dominantly dacite in composition in the Central Zone, and andesite in the Southeast Zone. These porphyry bodies have been emplaced into a sequence of intercalated carbonaceous sandstones and siltstones. Late stage flow banded feldspar porphyry dykes cut the dacite/andesite porphyry intrusions and result in visually sharp alteration contrasts where they cut previously altered hostrocks.

Diorite porphyry intrusions have been intersected at depth beneath the Southeast Zone and are inferred to be the deeper equivalents of the shallower level andesite porphyry bodies.

Basic sub-volcanic dykes crosscut the andesite / dacite intrusions and range from basaltic andesite to basalt in composition. Some of the basic dykes are pre-mineral, whereas others are post-mineral. Late, but pre-mineral, rhyolite dykes have been previously recorded, but were not observed in the cores analysed during this study.

Intrusion, hydromagmatic, fluidised and vein/dilational breccias are common in the core collected for this study.

Very similar lithologies and breccias are host to mineralisation in the Kelian deposit (van Leeuwen et al., 1990).

4. SEQUENCE OF HYDROTHERMAL EVENTS

Three main stages of hydrothermal alteration (replacement and deposition) have been recognised at Busang (Figure 1). It is postulated that these events are associated with the same overall hydrothermal system that evolved with time.

4.1 Stage I : Porphyry Event

This stage of hydrothermal activity is characterized by an initial phase of porphyry-style quartz vein development, followed by an episode of phyllic and propylitic alteration and veining. These porphyry-related assemblages are most extensively developed in the drillcore from the Southeast Zone

In the deep drillhole BDH 5, centimeter wide, sheeted to conjugate fracture sets host porphyry quartz \pm anhydrite veins at depths of 500-700m beneath the central part of the Southeast Zone. These veins are characteristically grey due to the presence of abundant primary and secondary liquid- and vapour-rich inclusions.

Halite daughter crystals are present in some of the liquid-rich inclusions and these are indicative of periods when the fluids were hypersaline (>25 wt% equivalent NaCl). The deposition of the porphyry-related quartz veins was polyphasal, and locally extended to very shallow levels.

Anhydrite occurs as intergrowths with, and inclusions in some of the porphyry quartz veins, although in most cases anhydrite deposition post-dates the quartz.

Extensive zones of porphyry-related, propylitic and intense phyllic alteration occur over an area in excess of 700m x 3.5km and to depths of more than 400m in the Southeast Zone, and are aligned along the NE-trending transfer structural zone.

The phyllic assemblage is dominated by coarse-grained 2M sericite (and locally muscovite) + quartz + pyrite. A purple anhydrite locally overgrows porphyry quartz in veins and is in turn overgrown by sericite. Dark blue-green tourmaline (schorl) is commonly associated with the quartz-sericite-pyrite wallrock alteration and overgrows sericite in veins. It is also associated with late dolomite-calcite deposition. Apatite occurs as minute grains with the phyllic alteration assemblage and commonly replaces wallrock mafic phenocrysts.

The propylitic alteration / veining is characterized by the presence of epidote + quartz + chlorite + carbonate \pm sericite and is peripheral to the phyllic alteration zones.

Fine grained milled matrix (fluidized) breccias locally cross-cut the porphyry-related quartz veins and are a precursor to the later carbonate-base metal system. In places these breccias contain clasts of earlier quartz vein material. The clasts are sealed in a comminuted matrix that is altered to illitic clay and/or sericite \pm quartz – carbonate – pyrite. It is speculated that these breccias may be related to phreatomagmatic (diatreme) events. A compilation of field mapping and drill core logging is necessary in order to fully evaluate the presence of a diatreme-maar complex at Busang, and this lies outside the scope of this study.

4.2 Stage II : Carbonate – Base Metal \pm Gold Event

Sheeted carbonate – base metal veins occur in the Central Zone to the north of the porphyry system, and are inferred to be genetically related to the dextral rotation on the NE-trending accretionary structures. In outcrop, it

was observed that the carbonate-base metal sulphide assemblages were also deposited along the fractured and brecciated contacts between the high level dacite intrusions and host sediments

Early quartz \pm adularia lines the veins and are overgrown by pyrite, arsenopyrite, sphalerite, galena and rare tennantite. Carbonates are intergrown with, but mainly overgrow, the sulphide minerals and infill the veins. This sequence of deposition is comparable to that described from many similar carbonate-base metal gold systems in the Southwest Pacific region (Corbett and Leach, 1998).

The carbonate base metal event extends into the Southeast Zone where it is present as base-metal-poor, carbonate-pyrite – marcasite stockwork veinlets and crackle breccia zones, and as rare discontinuous, sulphide-rich 'pseudo-veins'. At depth in the SEZ, the carbonate-base metal veins cut both the quartz-molybdenite and massive pyrite veins. Quartz-sericite/illite alteration accompanies the sheeted carbonate base metal veins in the Central Zone; whereas widespread, lower temperature, intense argillic alteration (kaolin – illitic clays) is associated with the carbonate-rich veins in the Southeast Zone where it has overprinted the earlier porphyry-related phyllic assemblages.

As in other carbonate-base metal systems, a wide variety of carbonate species are present. These range from early mixed Mn-Mg-Fe-Ca carbonates (kutnahorite, ankerite), followed by Fe-rich carbonates (siderite, Fe-dolomite) and late stage clear calcite. Mixed carbonates are commonly associated with higher temperature sericite-quartz wallrock alteration and vein deposition; whereas later Fe-carbonates are associated with kaolinite and lower temperature illite assemblages.

The carbonate minerals are overall more Mn-rich in veins in the Southeast Zone, and more Mg-rich in veins in the Central zone. Abundant manganese oxide in outcrop in the Southeast zone attests to the abundance of the Mn-carbonate veins.

Trace barite locally fills open spaces in the carbonate-base metal veins.

This is the main gold mineralisation event at Busang.

Both liquid- and vapour-rich inclusions were observed in the quartz from the porphyry veins indicative of two-phase (boiling) conditions during deposition. The liquid-rich inclusions homogenized at 260-446°C and freezing analyses indicated saline conditions (4-15 wt% equivalent NaCl). Some of the liquid-rich inclusions contain halite daughter crystals suggesting periodic hypersaline (>25 wt% equivalent NaCl) fluid conditions.

High temperature and salinity conditions during quartz deposition, the association with molybdenite mineralization and the sharp contacts of the sheeted veins are characteristic of 'B'-type porphyry veins.

Quartz, deposited during the early stages of the Stage II carbonate-base metal veins, contains only liquid-rich fluid inclusions and was deposited over a temperature range of 230-311°C (average of sixty-five measurements = 262°C) from a relatively dilute (1.7-2.4 equivalent weight percent NaCl) meteoric fluid.

Inclusions in carbonate minerals that overgrow the quartz in these veins, homogenized over a comparable temperature range as the quartz, but under significantly more saline (3.1-5.9 weight percent equivalent NaCl) conditions. An increase in salinity of the ore fluid during carbonate – base metal vein deposition is characteristic of these styles of systems (Corbett and Leach, 1998), and indicates an influx of magmatic-derived, metal-bearing brines into a dilute circulating meteoric system. The mixing of these fluids has been interpreted (Corbett and Leach, 1998) to result in associated gold mineralisation.

4.3 Stage III : Epithermal Quartz Veins

Rare quartz-rich, locally banded veins occur in the Central Zone drillcore. These are accompanied by stibnite and realgar-orpiment mineralisation and the late stage quartz veins appear to post-date the carbonate-base metal event.

4.4 WEATHERING / SUPERGENE

The samples collected for this study were selected in order to evaluate the primary or hypogene characteristics of the alteration and mineralization and therefore attempted to exclude the supergene effects of weathering. However it was noted that the oxidation, by groundwaters, of sulphide minerals in fractures and veins in places extended to depths of greater than 150m.

5. FLUID INCLUSIONS

Fluid inclusion heating and freezing analyses were carried out on quartz from Stage I porphyry veins and on quartz and carbonate from Stage II veins in samples from the Central Zone.

		Porphyry + Quartz Sulphide Event		Fluidised Breccias	Carbonate - Base Metal Event				Epithermal Event
		Quartz veins	Phyllic - Propylitic Alteration/Veins		Quartz - Kspar	Sulphide Mineralisation	Carbonates	Argillic Alt'n	Banded Quartz Veins
Hydrothermal Alteration and Deposition	Quartz	—————	—————		—————			—————	
	Anhydrite	-----	-----						
	K feldspar		----- ?		-----				
	Albite	-----							
	Tourmaline		—————						
	Apatite								
	Epidote		-----						
	Chlorite		-----				-----		
	Sericite		-----		-----				
	Illitic clay				-----		-----		
	Kaolinite						-----	-----	
	Calcite		-----				-----		
	Mn-Mg Carbonate					-----			
	Fe Carbonate					-----			
Barite						-----			
Fe - sulphide + Oxide	Magnetite	-----			-----				
	Pyrite		-----		-----				
	Pyrrhotite				-----				
	Arsenopyrite				-----				
	Marcasite						-----		
	Hematite				-----				
	Rutile				-----				
Base Metal sulphide	Molybdenite	-----							
	Chalcopyrite		-----						
	Sphalerite				-----				
	Galena				-----				
	Tennantite-Tetrahedrite				-----				
	Stibnite						-----	-----	
	Realgar						-----	-----	
Gold					-----		-----		

Figure 1 : Paragenetic Sequence of Alteration, Vein Development and Mineralisation, Busang Prospect, East Kalimantan

6. MINERALISATION

6.1 Base Metal Sulphide Mineralisation

Molybdenite is the only sulphide encountered in the porphyry-quartz veins, and occurs as fine-grained laths that are mutually intergrown with, and overgrowing, the quartz. Pyrite is virtually the only sulphide mineral associated with the phyllic and propylitic assemblages, however rare pyrrhotite, rutile and magnetite locally occur as inclusions in the pyrite.

Sulphides typically overgrow quartz in the carbonate-base metal sulphide veins and are intergrown with, and commonly overgrown by the carbonates. The sequence of sulphide deposition in these veins is :

- a) Pyrrhotite ± Magnetite
- b) Pyrite
- c) Sphalerite ± Arsenopyrite
- d) Galena
- e) Chalcopyrite
- f) Tennantite / tetrahedrite
- g) Marcasite

Sphalerite typically overgrows the Fe-sulphides, and is generally iron-rich in the Central Zone samples and iron-poor in the Southeast Zone veins. The sphalerite in the Central Zone exhibits compositional zonations from dark red-brown, Fe-rich cores to yellow / colorless iron-depleted rims.

Galena occurs as rare inclusions in pyrite and sphalerite, but commonly overgrows these minerals and is locally found as intergrowths in carbonate. Chalcopyrite occurs as blebs and stringers in sphalerite, but more commonly overgrows other sulphide minerals and is typically intergrown with carbonate. Tennantite occurs in only trace amounts in some of the SEZ core where it overgrows chalcopyrite, and contains small amounts (up to 1.2%) of silver.

Marcasite, indicative of low temperature conditions, is common in SEZ core where it is generally intergrown with late stage Fe-carbonate minerals and/or kaolinite, and is typically hosted in thin discontinuous dendritic veinlets.

6.2 Gold Mineralization

Mineragraphic analyses has shown that native gold/electrum mineralization is associated with the carbonate-base metal veins and the late stage epithermal quartz veins in core from the CZ. Gold was however not observed in polished thin sections prepared from the Southeast Zone core samples.

In the carbonate-base metal veins, gold occurs either as minute (4-40µm) inclusions in pyrite, sphalerite and galena; as larger grains (up to 100-200µm) that overgrow the sulphide minerals and extend into cavities and fractures, where it is intergrown with carbonate; and as a single large rounded / ovoid grains (200-250µm) that is mutually intergrown with late stage carbonate.

Over twenty-five gold grains were observed in six of the carbonate-base metal vein samples. The gold is not uniformly distributed along the veins, but typically occurs in discrete 'clusters' within one very small area. This 'nugget' effect is common in carbonate-base metal gold systems (Corbett and Leach, 1998) and makes sampling and resource estimating difficult.

Most of the gold grains observed in the core occur as minute (<20-40µm) inclusions in sulphides and therefore would be metallurgically refractory. However by volume / weight, the vast bulk of the gold (95% by volume) overgrows the sulphides and/or is intergrown with the carbonate minerals and therefore is expected to be relatively easily liberated during processing.

Base on data from electron micro-probe analyses, the gold exhibits a wide range in fineness (295-850), however the average fineness in each sample has a much narrower range of 562-774. The overall average of the fineness of the gold at Busang is 691 and this lies within the range of averages of other Southwest Pacific carbonate-base metal gold systems (Corbett and Leach, 1998).

A cluster of minute (6-80 µm) gold grains were also observed intergrown with quartz in a Stage III colloform banded quartz vein from one of the Central Zone core samples.

CONCLUSIONS

This study of the core samples from the Busang has recognized the progressive evolution of a large magmatic-related hydrothermal system that is comparable to that encountered in many similar systems elsewhere in the Pacific region (Leach, 1999).

Early stage porphyry quartz–molybdenite veins formed under hot, saline conditions, and are probably related to the initial exsolution of fluids from a cooling magma. Felsic magmas are typically associated with porphyry-molybdenite systems (Carten et al., 1993). It is therefore postulated that the late stage rhyolite dikes, that have been recognized elsewhere at Busang, are apophyses of a felsic intrusion at depth under the Southeast Zone, and that this intrusion is the likely source of the hydrothermal systems at Busang. Similar late stage rhyolite dikes are encountered at Kelian (van Leeuwen et al, 1990), and are probably genetically related to the gold mineralization in that deposit.

The presence of tourmaline and apatite in the extensive phyllic alteration assemblages in the Southeast Zone indicates that volatile-rich magmatic fluids were channeled over a large area. Similar large phyllic alteration halos have been recognized to be commonly associated with porphyry systems around the Pacific rim (Sillitoe, 2000).

Quartz-adularia veins were deposited during the establishment of a circulating-meteoric-dominated hydrothermal system. Late stage exsolution of metal-bearing brines along the margins of this system, deposited carbonate-base metal veins as these fluids cooled at shallow levels in the Central Zone. There is evidence that there was an outflow of these fluids into the Southeast Zone. This outflow formed extensive late stage carbonate-pyrite-marcasite veins, local base metal-sulphide-rich carbonate veins, and widespread argillic alteration that overprinted onto the earlier porphyry-related assemblages.

As the hydrothermal system continued to wane, there was local deposition of epithermal quartz veins and associated Au-As-Sb mineralization onto the earlier formed vein systems.

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APPENDIX 3

Unravelling the Alteration System at Busang

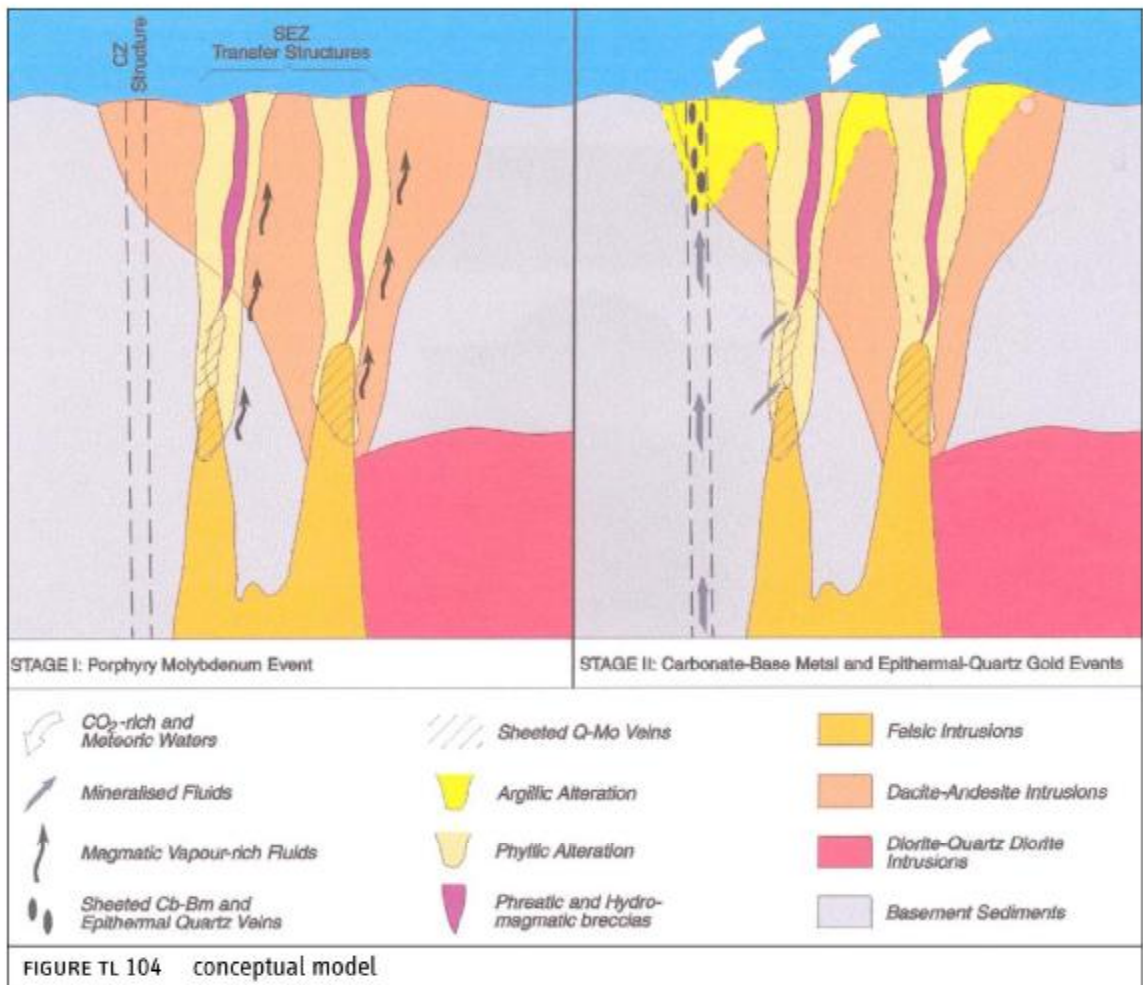
[Terry's work on Busang was characterized by meticulous detail. He was able to unravel the various phases of alteration and mineralisation and to present this as simplified, yet accurate, diagrams. The following is from Vol II of his Expert's Report]

“This study of the core samples from Busang has recognized the progressive evolution of a large magmatic-related hydrothermal system, which is comparable to many similar systems elsewhere around the Pacific Rim (Corbett and Leach, 1998; TL 104).

It is postulated that a felsic porphyry intrusion beneath the central parts of the South East Zone was emplaced at shallow crustal levels. Exsolution of fluids from this melt resulted in deposition of sheeted quartz – molybdenite veins, massive pyrite (\pm pyrrhotite, magnetite) and an extensive quartz-sericite-pyrite \pm tourmaline-anhydrite (phyllic) alteration assemblage. Similar large phyllic alteration halos have been recognized to be commonly associated with porphyry systems around the Pacific rim.

Late stage exsolution of metal-bearing fluids along the margins of this system are interpreted to have deposited carbonate-base metal veins as these fluids cooled at shallow levels in the region of the Central Zone. These fluids also migrated into the South East Zone and formed extensive carbonate-pyrite-marcasite veins, local base metal-rich carbonate veins and widespread argillic alteration that overprinted the earlier phyllic assemblages.

As the system continued to wane, there was a local deposition of epithermal quartz veins and associated Au-As-Sb mineralization.”



The Similarity of Kelian to Busang⁵

[Terry's petrological knowledge of Kelian and Busang was unique. He was able to demonstrate that the rarity of coarse visible may simply be a function of the distribution and nature of gold grains. This aspect was not only directly relevant to several of the "red flags" but is also relevant to exploration geologists in their evaluation and sampling of similar gold prospects. Terry's comments are quoted below with only minor edits (eg formatting and deletion of numbered references. Two of Terry's diagrams are included]

"The range in size of gold grains that were recognised in the polished thin sections from the drillcore at Kelian are comparable to those in the Central Zone. As outlined above, the larger grains in both deposits occur as free grains either intergrown with carbonates or in fractures.

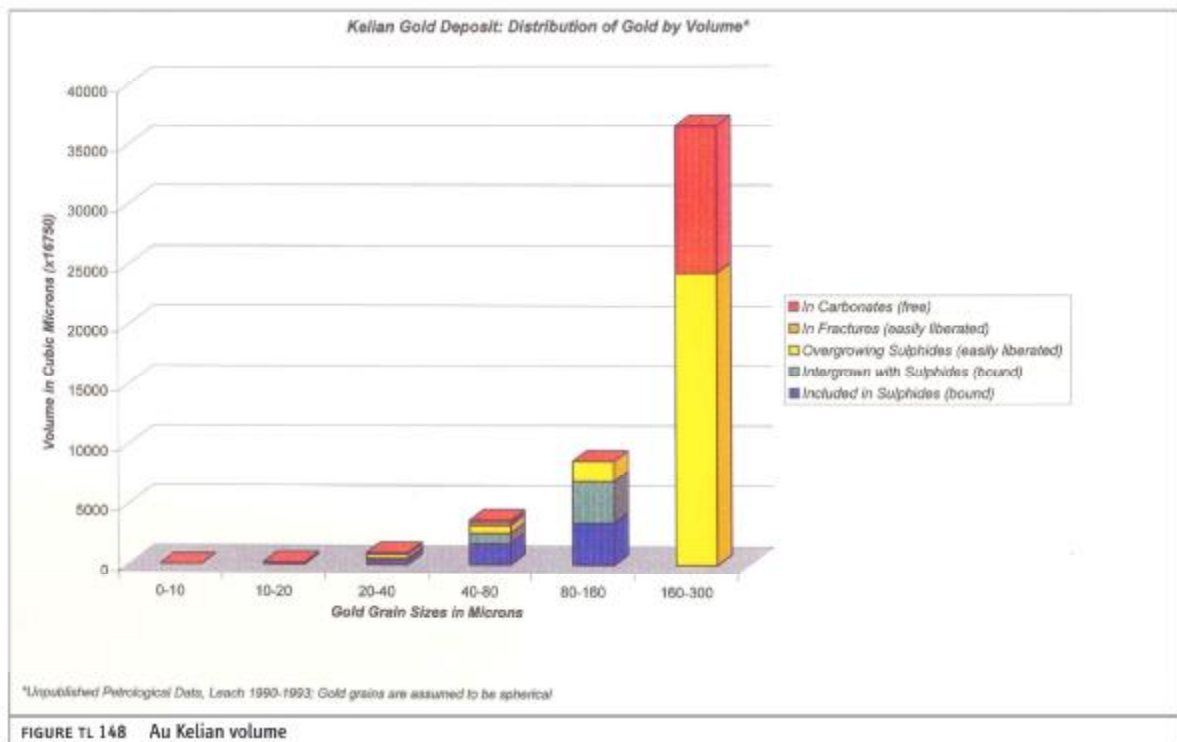
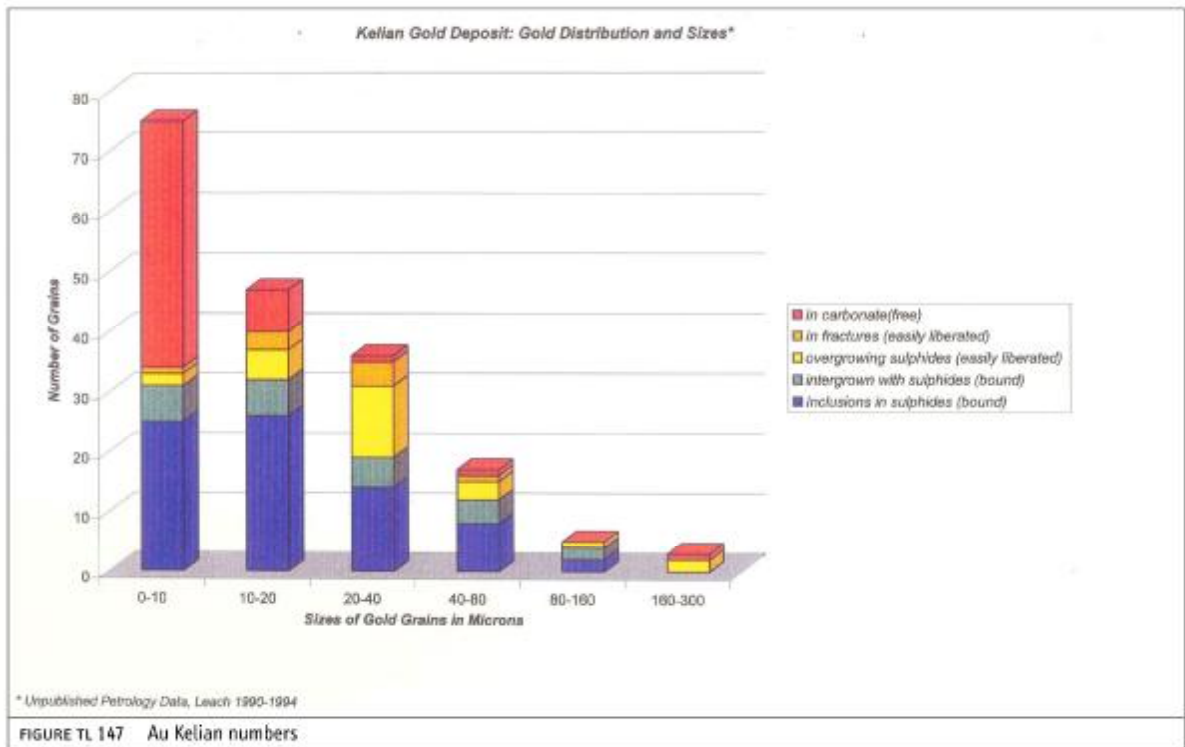
Kelian:

- There is considerable coarse gold at Kelian based on test work. Coarse gold ($> 100\mu$) is most common (up to 45%) in ore zones where carbonates are most abundant. (Since carbonates are much more common than sulphides in the South East Zone,, most of the gold in the South East Zone would be expected to be coarse grained.)
- The gold grains observed under the microscope range from 1μ to $> 200-250\mu$.
- The microscopic gold at Kelian exhibits a regular distribution.
- The highest percentage (by number) of gold occurs in the finest fraction (41% in the $1-10\mu$ range) and the smallest percentage in the coarsest fraction (4% in the $80-300\mu$ range).
- Gold is irregular to ovoid as inclusions in sulphides (finest grains), irregular to flattened in fractures and overgrowing sulphides, and lobate to rounded intergrown with carbonates (coarsest grains)."

"The Kelian gold mine is operated by Rio Tinto Indonesia (RTI) and is located approximately 150km southwest of Busang in East Kalimantan on the island of Borneo. Many geologists who have worked on Busang have noted numerous close similarities to the Kelian gold deposit. Felderhof et al. (1995) also recognised the close similarities between Busang and Kelian. Although only two publications have been made public on Kelian during the exploration and development of Busang in the mid-1990s (van Leeuwen et al., 1990 [8]; Corbett and Leach, 1998 [25]), information was readily shared between RTI and Bre-X geologists (van Leeuwen per comm). Therefore, many of the procedures, as well as many of data interpretations made at Busang were made based on the understanding of the Kelian deposit."⁶

⁵ Expert Report Vol 1, p 138

⁶ Expert Report Vol II, p 128



For Those who Believe Gold Mineralisation must be accompanied by Quartz Veining⁷

[This addresses one of the “red flag” complaints of Strathcona]

- “Strathcona expected to see geology typical of high-grade epithermal deposits, which generally refers to banded quartz vein development. The absence of silicification and banded epithermal quartz veins was therefore a ‘red flag’ to Strathcona.

However, very high grades in epithermal gold deposits are not restricted to quartz veins, but can also occur in a number of other ways :

- Carbonate-rich and sulfide-poor veins and vein breccias like in the Northeast Zone at Kelian.
- Vanadium mica (roscoelite) – pyrite veins and breccias like at Porgera and Mt. Kare in Papua New Guinea.
- Arsenic-pyrite rich shears, breccias and disseminations as in the Deep Post, Deep Star and Meikle deposits in the Carlin trend where gold mineralisation is hosted in calcareous rocks (limestone), as well as in intrusions.”

⁷ p54 Vol I Expert report

Kelian – Busang Comparison : Alteration And Mineralization⁸ *

	KELIAN		BUSANG	
	Prampus Zones	North-East Zone	Central Zone	South-East Zone
Surface Alteration and Mineralization	<p>Outcrop – altered pyritized rock in only small section of Kelian River</p> <p>Subsurface – soil and pits defined alteration / mineralization over area of about 1 km²</p>		<p>Outcrop : : altered and mineralized samples in headwaters of Sungai data Busang</p> <p>Subsurface : soil and trench data defined alteration and mineralization of area of about 0.6 km²</p>	<p>Outcrop : limited sulfide outcrop in creeks (Westralian)</p> <p>Alteration and mineralization in 600 x 700m area east of Busang River (Olii, 1993)</p> <p>Subsurface : drilling defined alteration and mineralization associated with shear zones over area of more than 2.5 km²</p>
Stages of Events	<p>Stage I : Quartz-sericite-adularia-chlorite-carbonate ± epidote alteration and veining; pyrite – arsenopyrite mineralization</p> <p>Stage II : Carbonate – base metal sulphide –pyrite ± quartz ± arsenopyrite and breccia fill. <u>Gold ± Silver</u> mineralization</p> <p>Stage III : Kaolinite- carbonate – cinnabar. Marcasite ± pyrite</p>		<p>Stage I : Quartz-sericite-pyrite chlorite (K-feldspar ± tourmaline). Grades to porphyry quartz veins and molybdenite ± chalcopyrite mineralisation at depth in SEZ.</p> <p>Stage II Carbonate – base metal sulphide – pyrite ± arsenopyrite ± quartz veins/breccia fill. <u>Gold</u>. Base metals very rare in SEZ.</p> <p>Stage III Kaolinite – carbonate –pyrite. Marcasite in SEZ</p> <p>Stage IV :Epithermal quartz ± stibnite ± <u>Gold</u>. Trace realgar & orpiment</p>	
Dominant Wallrock Alteration Minerals	Sericite > Quartz > Adularia > Carbonate > Pyrite > Chlorite (in tuffs and sediments)		Sericite ≥ Quartz > Carbonate ≥ Chlorite ≥ Pyrite	Sericite ≥ Quartz ≥ Carbonate > Clay > Pyrite
Dominant Vein Types	Sulphides > Carbonate > Quartz (High BM content) Carbonate > Sulphide in 255 Zone	Carbonate > Sulphides (overall low BM content)	Carbonate ≥ Sulphides (Pyrite ≥ BM sulphides) > Quartz	Carbonate > Pyrite (very low BM)

*van Leeuwen et al. 1990 [8]; Leach (1997) [17]; Levings & Ogieman (1989) [4]; Olii & Zufrein (1993) [19]; Bre-X map (1994) [20], Thompson (1996) [15]

⁸ p 165 Vol II, Expert Report

**THE TERRY LEACH SCHOLARSHIP
FOR POSTGRADUATE RESEARCH IN
PETROLOGY & GEOCHEMISTRY AWARDED TO
Ms ZARAH HEYWORTH BSc (HONS 1) PHD STUDENT (UQ)**

Hellman & Schofield Pty Ltd is pleased to announce that a scholarship to honour the life and work of Terry Leach BSc (Carleton University), MSc (Hons 1, Auckland University), M.Soc.Econ.Geol has been awarded to Zarah Heyworth . Terry passed away on 28 February, 2007.



Zarah's research is primarily focused on understanding the chemical fluxes and dynamics of volcanic and hydrothermal systems within the Australian-Pacific margin. She was also awarded the AIG-Terra Search postgraduate bursary to do an oxygen isotope study at the ANU on sea-floor samples from the Vanuatu backarc basin.

The Terry Leach Symposium will be held on 17 October 2007 at the Kirribilli Club, Milsons Pt, Sydney (see <http://www.smedg.org.au> for details).

NEW PERSPECTIVES ON BUSANG
P L Hellman B Sc (Hons) PhD FAEG MGSA FAIG

The red flag warning signs at Busang signifying unusual and irregular results were numerous and obvious according to the critics. These alleged signs ranged from the absence of visible gold in drill core to the co-existence of marcasite with secondary gold.

Curiously, no evidence of tampering, contradictions, irregularities or any substantive issues relating to the validity of the exploration data are known to have been reported by any of Bre-X's consultants or visitors to the site prior to Freeport's due diligence drilling activities. This is despite numerous visits to Busang by representatives of many mining and exploration companies such as Aurora, Barrick (twice), CRA (twice), Echo Bay, Placer and Teck.

A little publicized, but extensive, review by one of North America's best known and respected minerals auditing groups, MRDI Inc, was commissioned in October 1996 specifically to assess the work of Bre-X at Busang. That work stated:

"Our principal conclusion is that the exploration work is being done to a high standard"

It is difficult to reconcile this and many other positive comments with the numerous criticisms made by commentators since the salting was discovered. Is it credible to argue that all of the many professionals who worked on the Busang project were negligent by either not recognizing or ignoring the many obvious warning signs? They included specialists in mineralogy, metallurgy (including gravity processing and comminution), fatal flaw audits, epithermal and tropical geology, sampling and assaying.

The talk will demonstrate that there were many results that constitute "green flags" or positive indicators. These include the morphology of the gold grains and the spatial continuity of the gold mineralisation. A green flag that has recently emerged is extensive gold mining by national miners.

Using new gold fingerprinting data from the little-known Sheraton Project, the talk will show that there is no substance to the well-accepted belief that the tampered gold was purchased from a local gold seller. An exciting spin-off from this type of work is its potential application to identify the source and character of gold (and other grains) found in samples such as panned concentrates.

⁹ Abstract of talk given in Auckland, AusIMM meeting, 2002