Geohazard and Infrastructure Modeling and Monitoring in 3D with the Mapped Underworld Dimension (MUD™) System:

Auracle Geospatial

CASE STUDY: PIPE STALKER™

2022

AURACLE GEOSPATIAL

OVERVIEW

Auracle is a remote sensing and geospatial technology company specializing in airborne and satellite applications that serve global clients in mineral exploration, oil and gas, engineering, natural resource management, waste management, railways and defense.

Auracle's technology maps and models the Earth's surface down to bedrock—hundreds of meters underground and through water. The 3D **M**apped **U**nderworld **D**imension (MUD™) Model, the foundation of our technology, makes it possible to "see through" water, vegetation, ice, trees, rocks and soil to identify structures and lithologies. This technology makes it possible to explore and map, from space, with millimeter-level accuracy, day or night, through all weather, and in remote or inaccessible areas. With the MUD™ system, we can measure as little as 2mm of movement in any location, in 3D. Auracle's systems require no permits, are cost effective, are completely discrete, and provide actionable information to key decision-makers.

Auracle also generates highly accurate Continuous Surface Elevation Models© (CSEMs), specializing in shallow lake and river bottoms. These elevation models replace manual surveys of shallow lakes and rivers in geophysics, particularly gravity surveys and provide valuable terrain information needed in exploration.

Using high-definition satellite video and imagery, we construct Hyperspatial Digital Elevation Models© (HDEMs) as a monitoring system that identifies subtle movements and changes in infrastructure such as pipelines, dams, ports, landfills, roads, and bridges. This early warning system supplies our clients with a cost-effective way to monitor and manage potential environmental damage caused by geo-hazards, industrial activities, and natural disasters.

Imbedded in each project is our commitment to environmental responsibility, efficiency, and economic success. Our methods create no unnecessary human footprint, require no social license, and do not cause cultural interference.

TECHNICAL ADVANCEMENTS

MAPPED UNDERWORLD DIMENSION (MUD™)

Over the last 20 years, Auracle has developed a unique method of using satellites and other airborne systems, to monitor, detect and map the impact of structural movement on surface and subsurface assets such as pipelines, railroads, bridge abutments, slopes, mines, and other critical infrastructure and assets. Auracle's pioneering work began in satellite hyperspectral and synthetic aperture radar. Further advancements in satellite radar tasking and analytic systems paved the way to look through vegetation, land cover and water providing the ability to define subsurface geological structures, features and units. With exposing the non-outcropping near surface, Auracle corrected and improved geological maps and models with structural features including non-apparent strike and dip.

In 2012, Auracle began experimentation to identify and analyze features and combinations of variables that could be used as surface and subsurface 'training sites', from which signals data would be developed as search parameters for geohazards. By combining proprietary acquisition and processing algorithms, Auracle developed a robust automated tool for identifying and monitoring geohazards. This system works at, near and under the earth's surface to "see" through deep vegetation, ice, snow, water, and overburden. The MUD™ system was born.

Our positionally accurate fused radar technology uses subsequent satellite images collected over time to provide a reliable "state of change" analysis. This allows Auracle to alert and define existing and potential hazards for operators. The MUD™ system replaces point or grid-based surveys to precisely detect movement or deformation under the Earth's surface, resulting in actual not derived ground information.

KEY FEATURES

- Monitors surface and subsurface movement well in advance of events that threaten infrastructure
- Operates day and night, through all weather
- Measures as little as 2 mm of change in 3D
- Creates no human footprint and requires no permit

MUD™, the foundation of this monitoring technology "sees" structure to monitor geohazards through:

- 100 meters of water
- 100 meters of sand and tills
- dense valley vegetation
- 30 meters of glacial ice and deep glacial tills

Satellite Borne C Band Synthetic Aperture Radar Monitoring Types					
	Conventional Change Detection				**Auracle**
	CCD	InSAR	DiffinSAR	PSinSAR	**3D MUD™**
Monitoring Frequency	>20 Days	>20 Days	>20 Days	>20 Days	**<40 Hours**
2.5mm Displacement Minima Detectable	x	✓	✓	✓	✓
Complete Area	x	x	x	x	✓
Eliminates Layover	x	x	x	x	✓
Eliminates Distortion	x	x	x	x	✓
Uniform Spatial Accuracy	x	x	x	x	✓
Models and Monitors on Surface	✓	✓	✓	✓	✓
Models and Monitors Under Land Surfaces	x	x	x	x	✓
Models and Monitors Under Water	x	x	x	x	✓

Table 1 – SAR Monitoring Types Comparison to MUD™

POINT CLOUDS AND SECTION VIEWS

Point clouds are produced, in cases of land use, from the stereo radar pair using Auracle's proprietary algorithm. The clouds are then fused and further analyzed in 3D for density using a search radius of 5 meters and are not vertically exaggerated. In addition, these 3D Point Clouds represent competent reflectors at and under the earth surface which can be analyzed for their variability and used to correct and aid 3D seismic and other geophysical inversions. Auracle's 3D Point Clouds represent the subsurface and like LiDAR can be viewed using common XYZ or LAZ format software.

The following figures illustrate the ability to identify the differentiation, showing the 4 variables previously discussed:

- Difference in densities
- Difference in textures
- Differences in resistivities
- Structural bounds

In addition, signals representing these variables form the signature of:

- Underlying Bedrock
- Various composition alluvial facies
- Saturated material

CASE STUDY: PIPE STALKER™

The Pipe Stalker™ case study provides evidence of an effective and efficient application for cutting time and cost in locating kimberlite occurrences.

CASE STUDY: Pipe Stalker™

A field of 10 established occurrences on the Nunavut mainland was used as a test site.

The following images are visual evidence of the viability of Pipe Stalker™ in the search for new kimberlite pipe-type occurrences:

Image 1: This is the location of the occurrence in a high-resolution color satellite image. The area is covered with overburden and contains numerous water bodies. There are no apparent signs of the blind, and in some parts under water, pipe occurrences.

Image 1. Nunavut, high resolution satellite image

Image 2: This is a plan view of the Pipe Stalker™ radar cloud. The very dark outline represents a texture-density derivative.

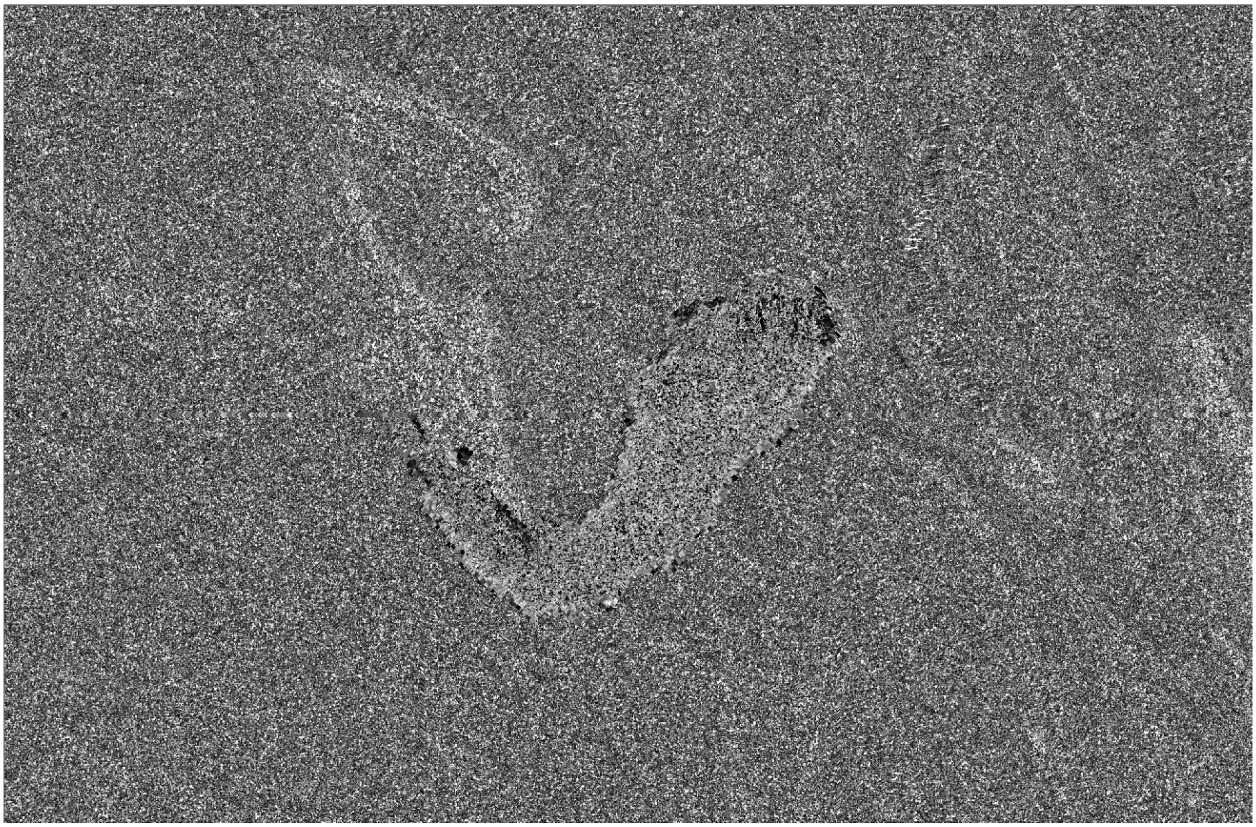

Image 2. Nunavut, high resolution radar image

Image 3: This is the same plan view with the published mapped outline of the established kimberlite occurrence in green. The mapped outline very strongly spatially correlates to the very dark texture derivative outline.

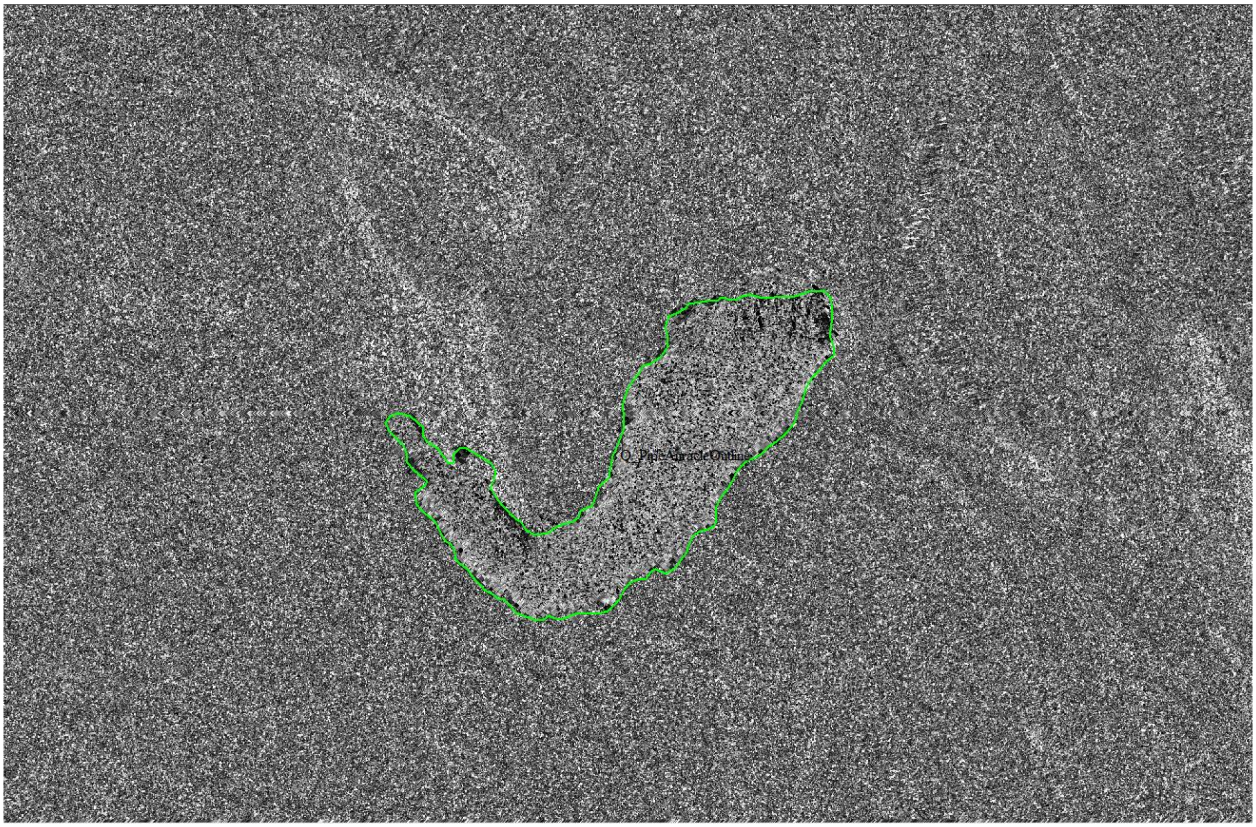

Image 3. Kimberlite occurrence outlined in green

Image 4: The yellow shading defines a zone of fractured material detected by Pipe Stalker™ and texture differential surrounding the mapped kimberlite pipe occurrence.

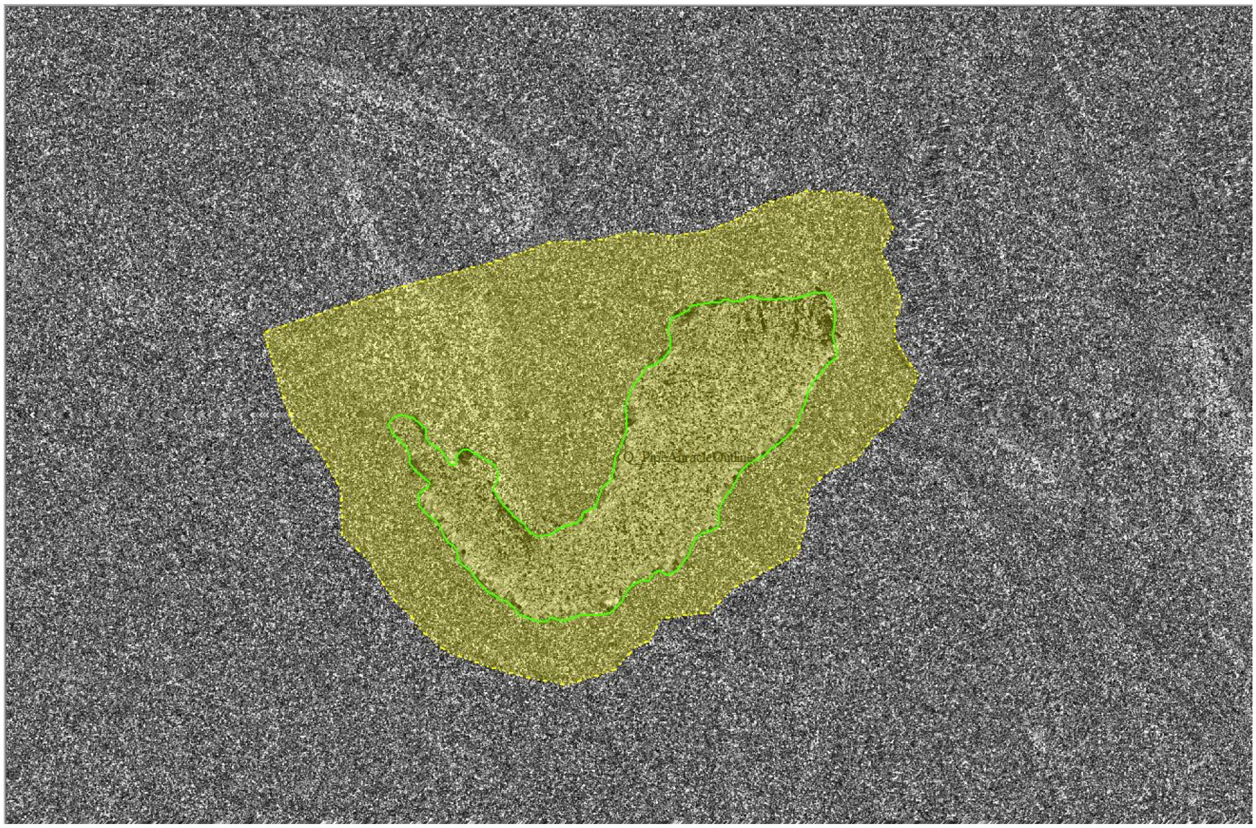

Image 4. Yellow zone outlines fractured material

Image 5: An East-West red linear feature forms an apparent northern boundary to the yellow fracture zone.

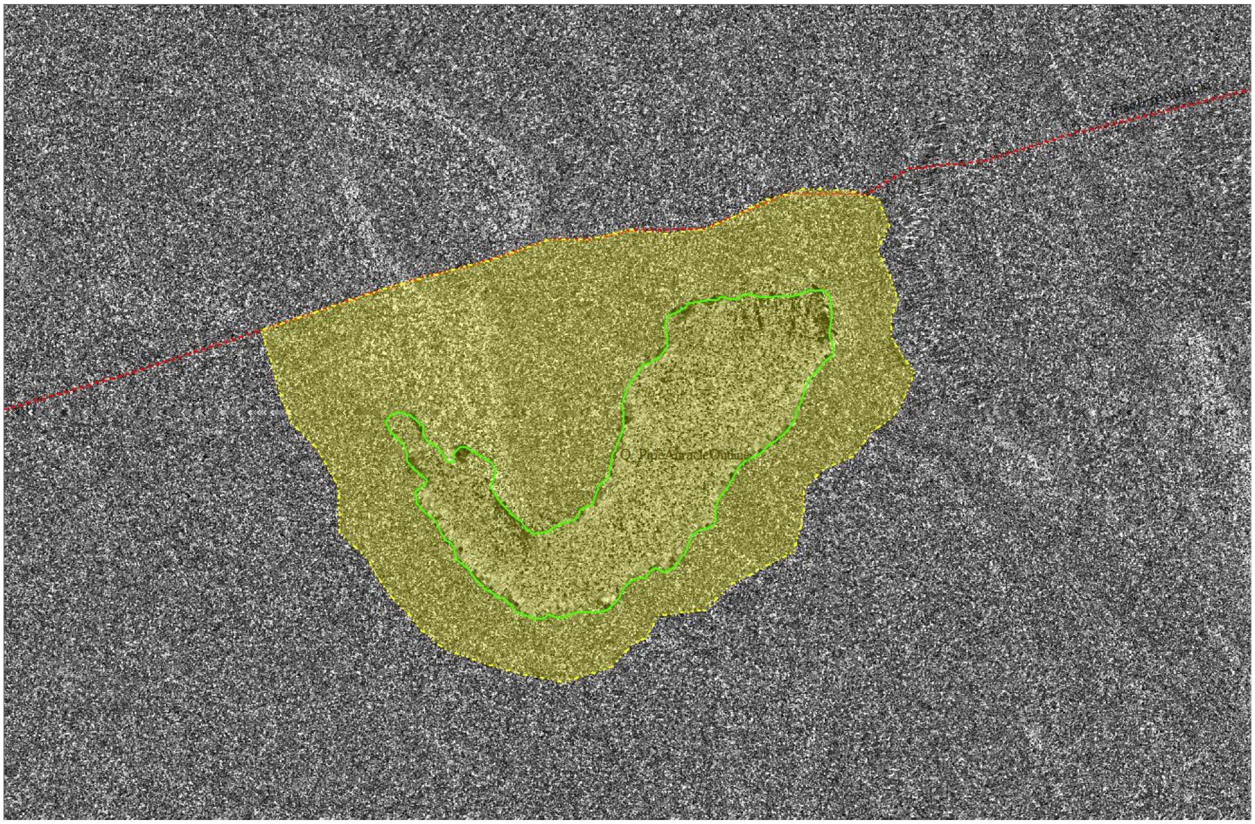

Image 5. Red line highlights apparent northern boundary

Image 6: Water bodies (in transparent blue) are overlain on the model to show the areas of water penetration by Pipe Stalker™. Note by using Pipe Stalker™ water presence is not a concern in identifying subsurface and underwater structures.

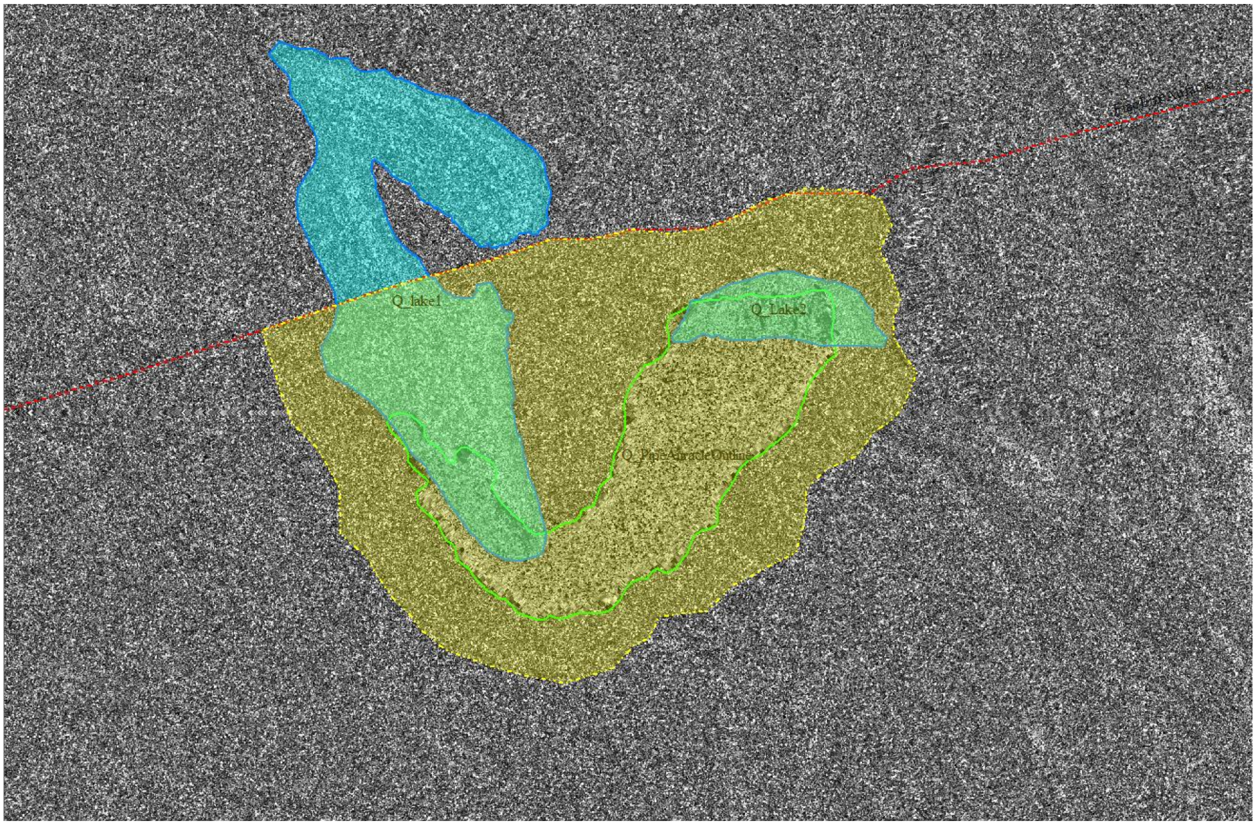

Image 6. Waterbodies overlay

Image 7: A cross-section delineation from NW to SE intersects the model to provide locational information for 3D volume slices which are shown in the next images.

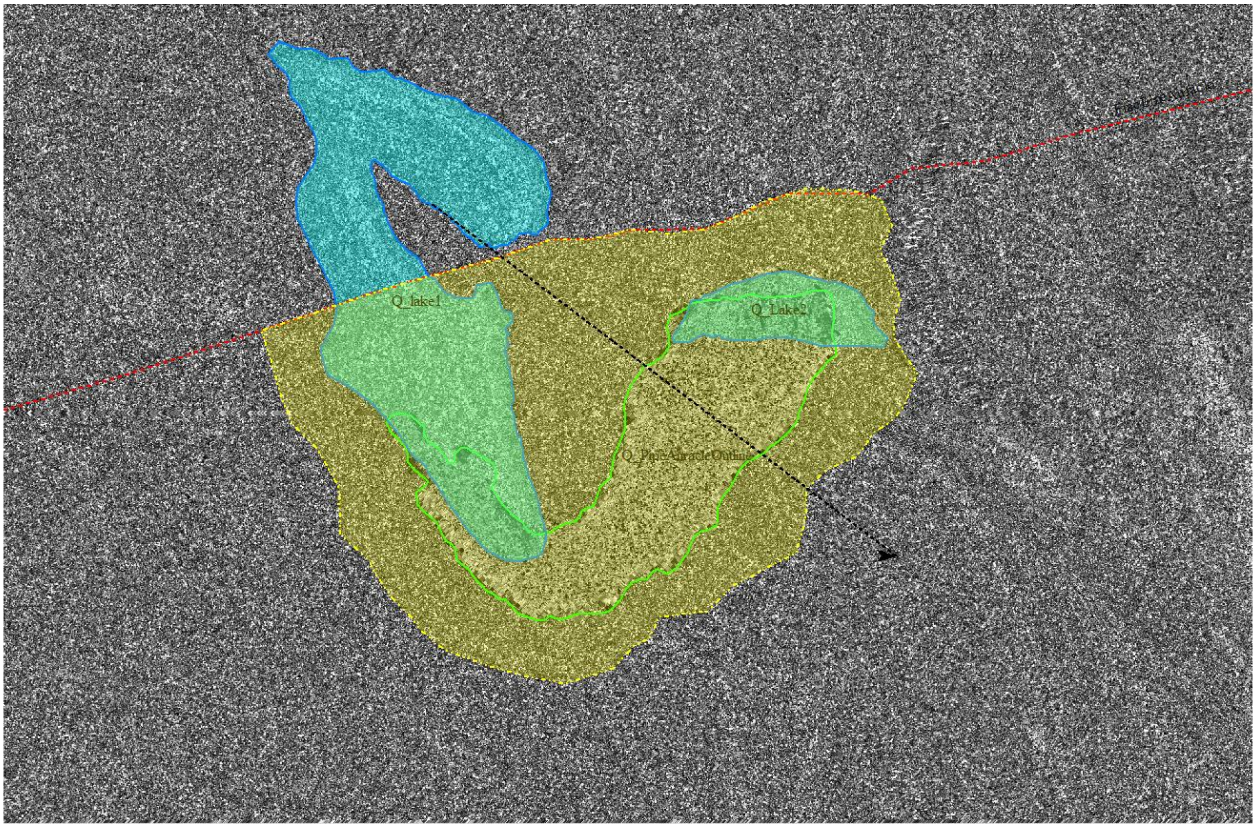

Image 7. NW-SE cross-section reference

Image 8: A second SW to NE section line is delineated showing another 3D volume slice orientation.

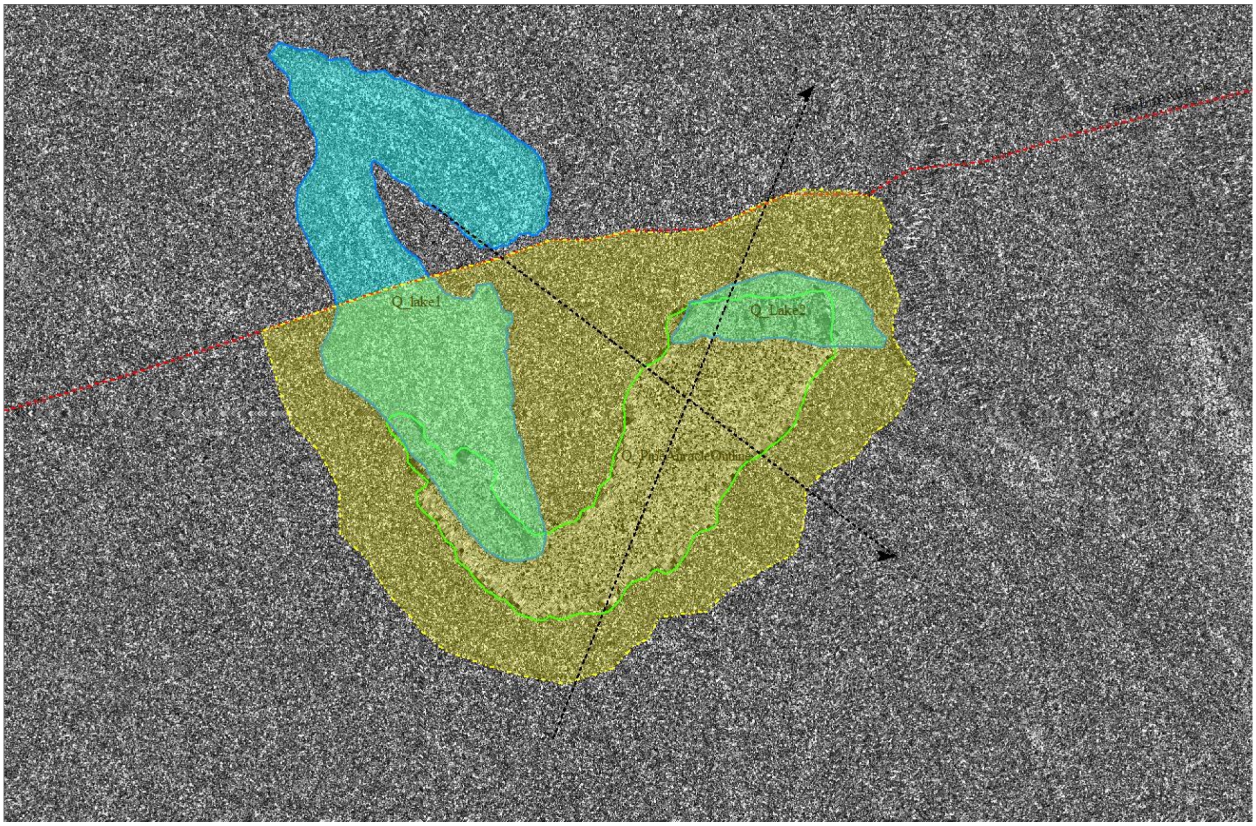

Image 8. SW-NE cross-section reference

Image 9: NW-SE section tomographic or 3D volume slice through the point cloud model.

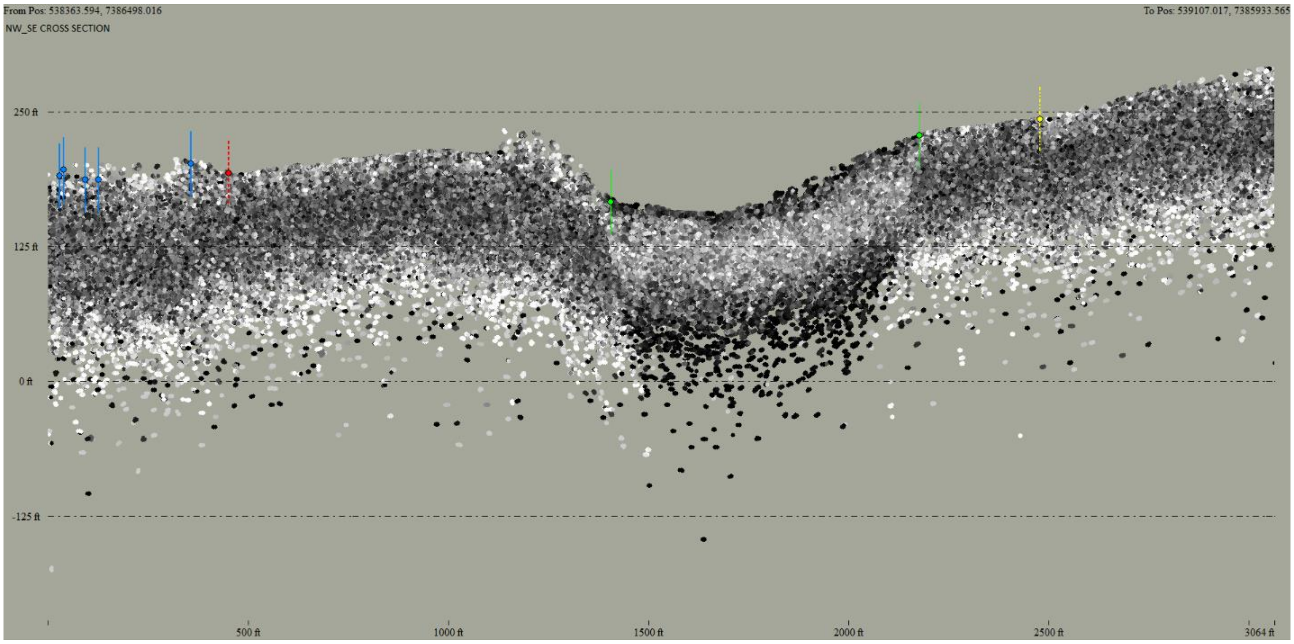

Image 9. NW-SE cross-section

Image 9a: The structural and density margins of the pipe below grade.

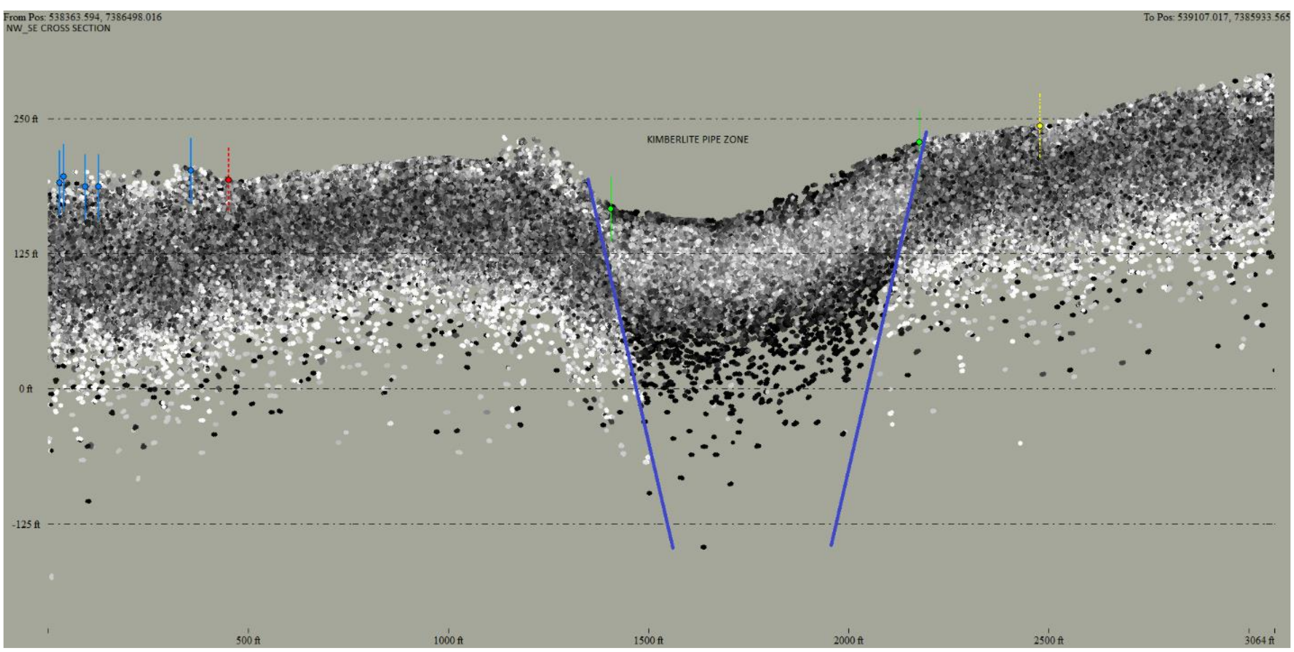

Image 9a. NW-SE cross-section margins of pipe zone

Image 9b: The structural and textural margins of the fracture zone surrounding the kimberlite pipe.

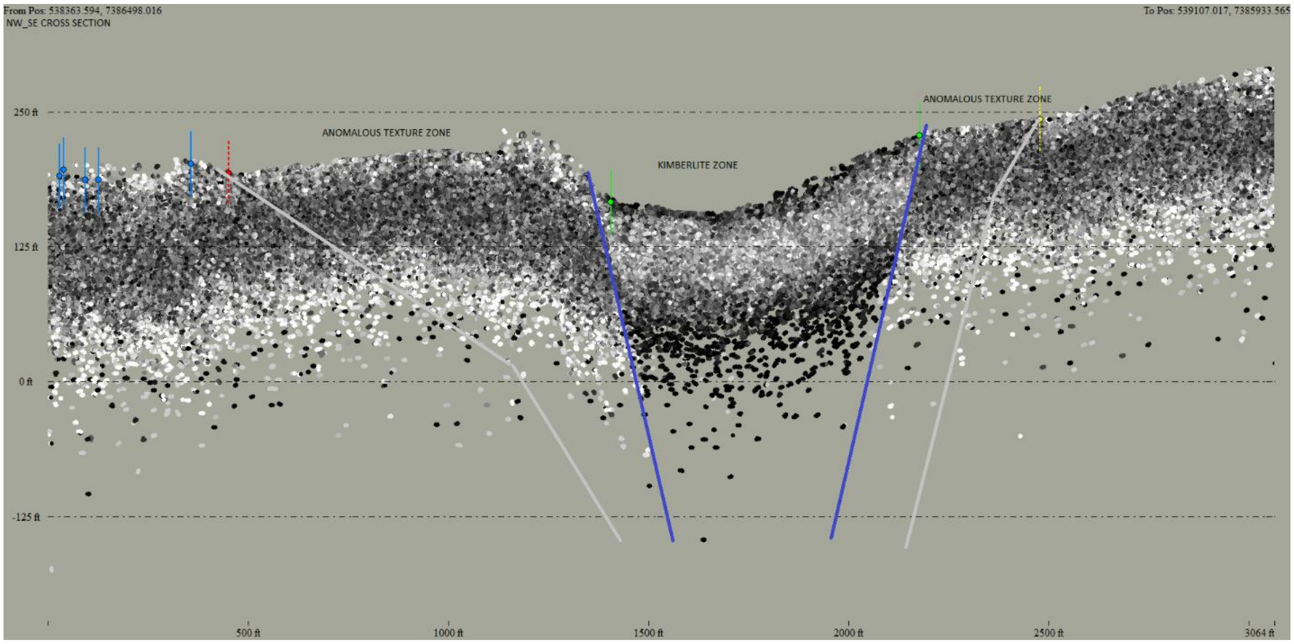

Image 9b. NW-SE cross-section margins of fracture zone and pipe zone

Image 10: SW to NE section tomographic or 3D volume slice through the point cloud model.

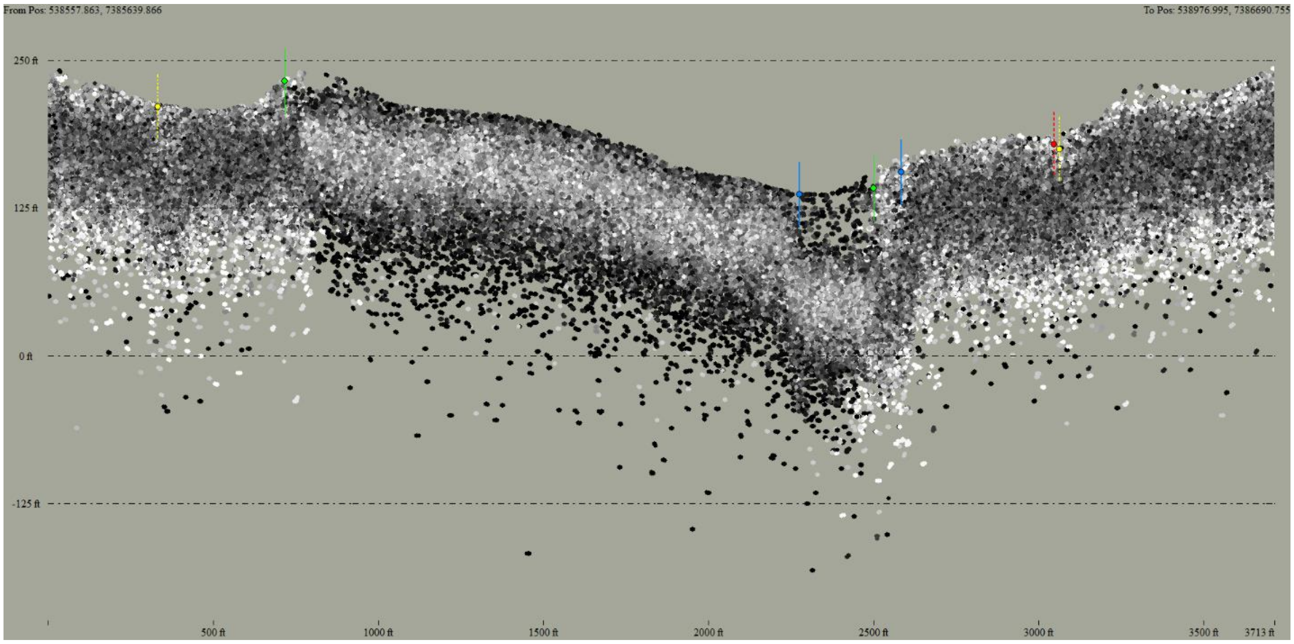

Image 10. SW-NE cross-section

Image 10a: The structural and density margins of the pipe below grade.

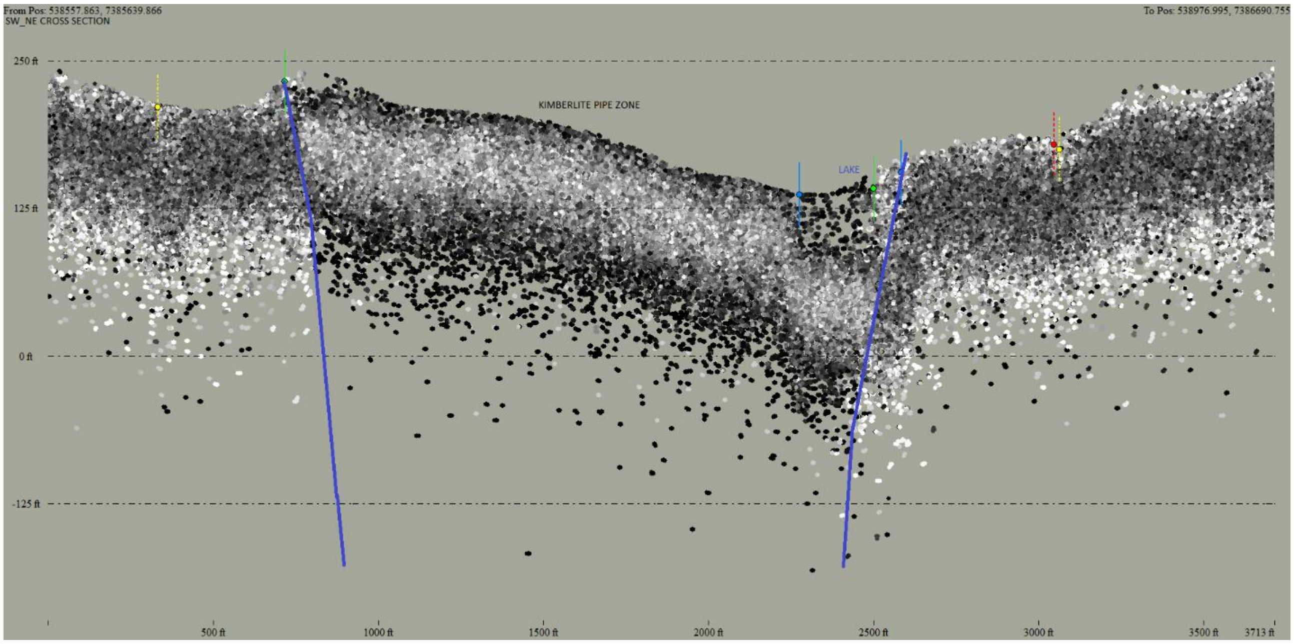

Image 10a. SW-NE cross-section margins of pipe zone

Image 10b: The structural and textural margins of the fracture zone surrounding the kimberlite pipe.

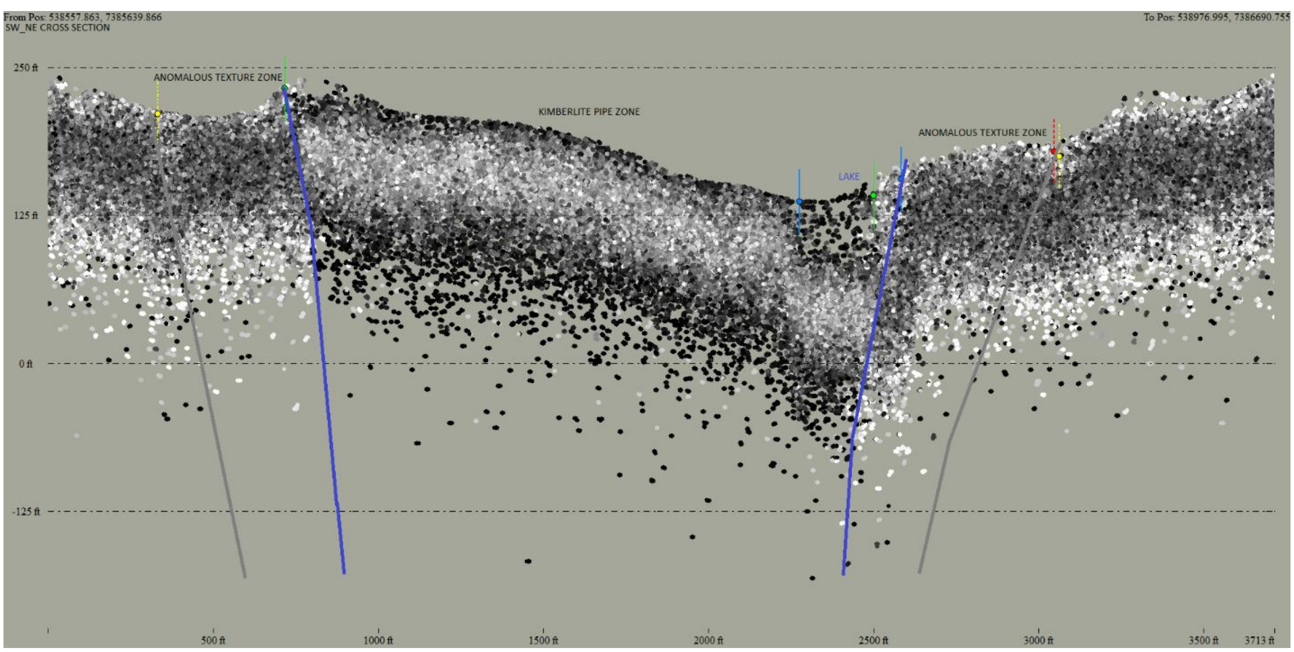

Image 10b. SW-NE cross-section margins of fracture zone and pipe zone

CONCLUSION

The Pipe Stalker™ system discretely and anonymously searches for the signal combinations that indicate probable kimberlite-pipe type occurrences in heavy overburdened areas and water cover. This ability reduces the cost and time to advance exploration and development. The work can be conducted over large, inaccessible areas, year-round. The Pipe Stalker™ system creates no human footprint or other environmental impact and requires no permits.

THIRD PARTY OBSERVATIONS
by Paul Metcalfe Ph.D. P.Geol. FGS

My training is predominantly in the fields of volcanology, igneous petrology and mineral exploration. I have experience in remote sensing, particularly the interpretation of processed satellite-based Synthetic Aperture Radar (SAR) data. In these capacities, I participated in the initial SAR assessment of the test area described herein but have never visited the property itself.

For clarity, I participated neither in development nor application of the Pipe Stalker™ system. Furthermore, I will receive neither direct nor indirect consideration from this review, excepting only remuneration for my time.

The contrast in physical properties between the mapped kimberlite pipe and the surrounding country rocks detected by and delineated in the Pipe Stalker™ could not be clearer. The peripheral shatter (or fracture) zone common to ultraplinian eruption vents is also clearly distinguishable by its physical properties. In addition, the termination of linear features in the surrounding country rocks clearly delineates its outer boundary. Furthermore, moderately to steeply dipping discontinuities within the shatter zone, unremarked in this study, are consistent with fractures commonly developed on a variety of scales in post-eruption conditions of decompression and subsidence.