Kick-start development of green energy sources

Airborne Geothermal Exploration

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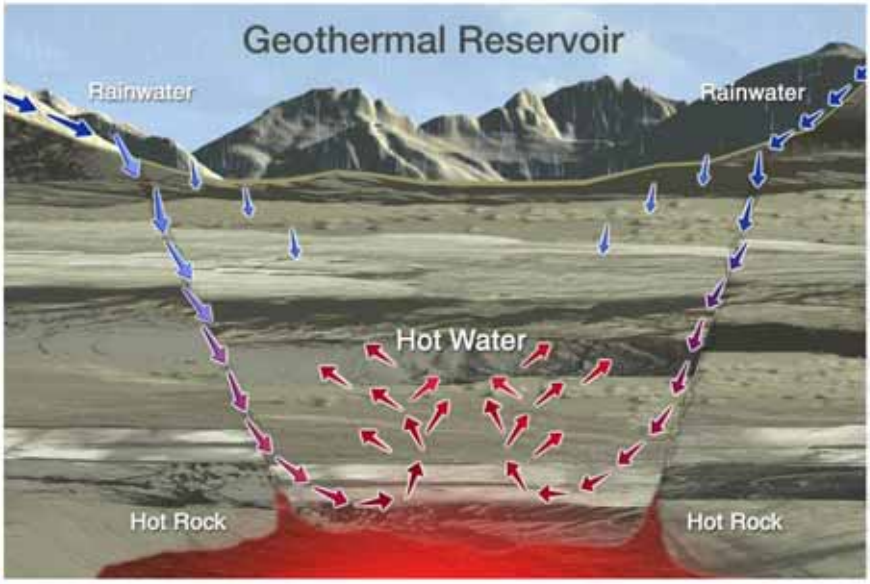
Objectives

- Fast track the geothermal exploration affords
- Reduce the costs for geophysics exploration and deposit estimations
- Have higher probability of success in drilling of explorations and preproduction wells
- Have data also prepared for
  - Preliminary Planning and Approvals
  - Engineering planning and construction
  - Environmental Impact Assessment

Theoretical background

- Hydrothermal - heat-carrier fluid, liquid water or steam depends on the pressure and temperature. 1 to 10km deep – Lidar, Hyperspectral TIR LW
- Geopressurizaded - similar to hydrothermal but in deeper places, heat-carrier fluid usually between 100 and 200ºC, 1000 bars and are very salty – Lidar, Broadband Thermal or Hyperspectral TIR LW
- Hot stones - waterproof stones with a temperature between 100 and 300ºC and next to the magmatic bags - Hyperspectral TIR LW



Technical solution

- Identification of the basic terrain structures
- Detection of the geological fault lines
- Evaluate these fault lines in their properties as of
  - are they still thermal active
  - are there clay minerals around the fault line on the surface
  - are their carbon monoxide and sulphurous gases coming out of the fault lines

Technical solution

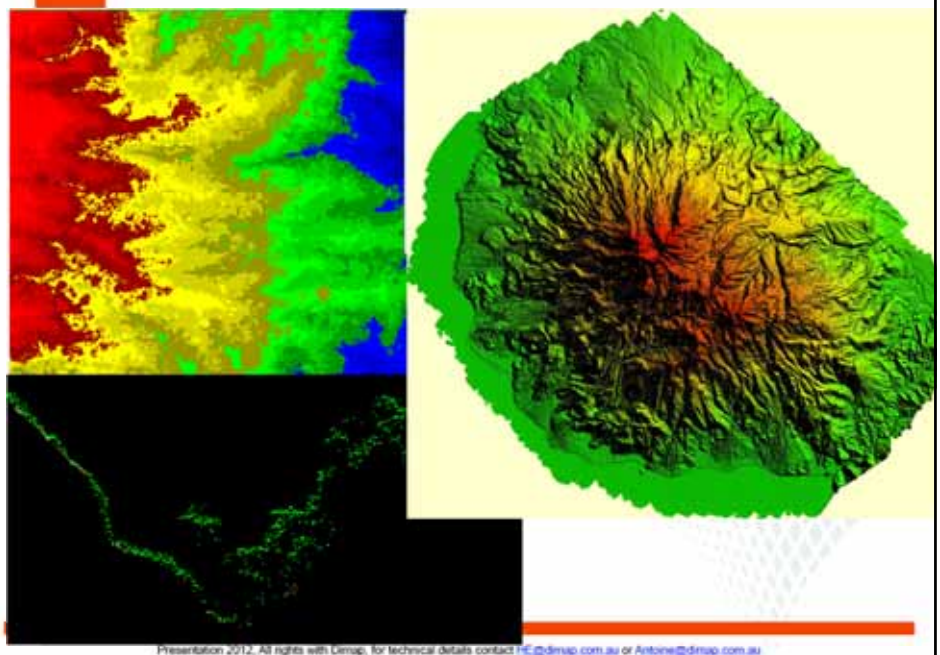
- Multisensory airborne approach combining required sensors in one flight:
  - Topographic high power airborne Lidar systems with full waveform data collection to penetrate also rainforest structures
  - Reflective Hyperspectral sensor in the visible to short wave infrared band (400 to 2500nm)
  - Thermal Hyperspectral sensor (7600 to 11800nm)

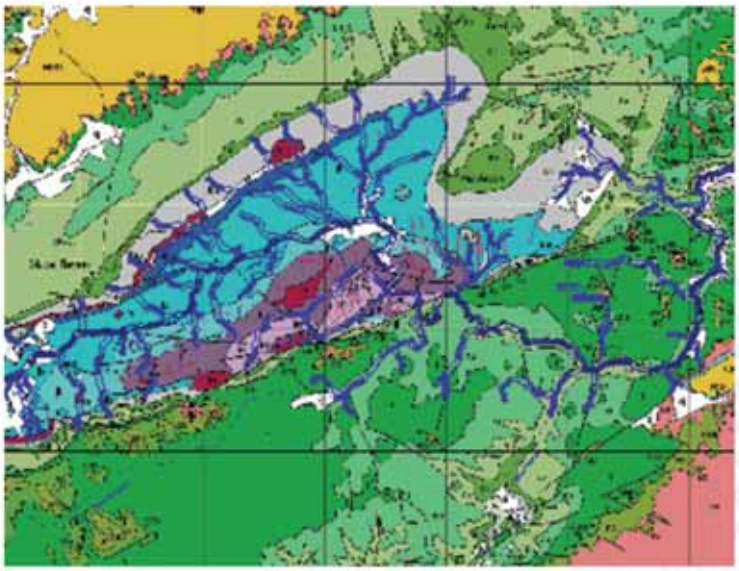
Positioning of the technical solution of airborne operations

- Satellite data for area detection, but not capable of identifying details for planning – very suitable to identify the area of interest for the airborne operations
- Airborne operation (typically 50 to 500 sqkm)
- Geophysics and ground exploration work on the identified thermal potential areas after the airborne survey
- Drill operations for exploration and semiproduction

Detection of Fault lines

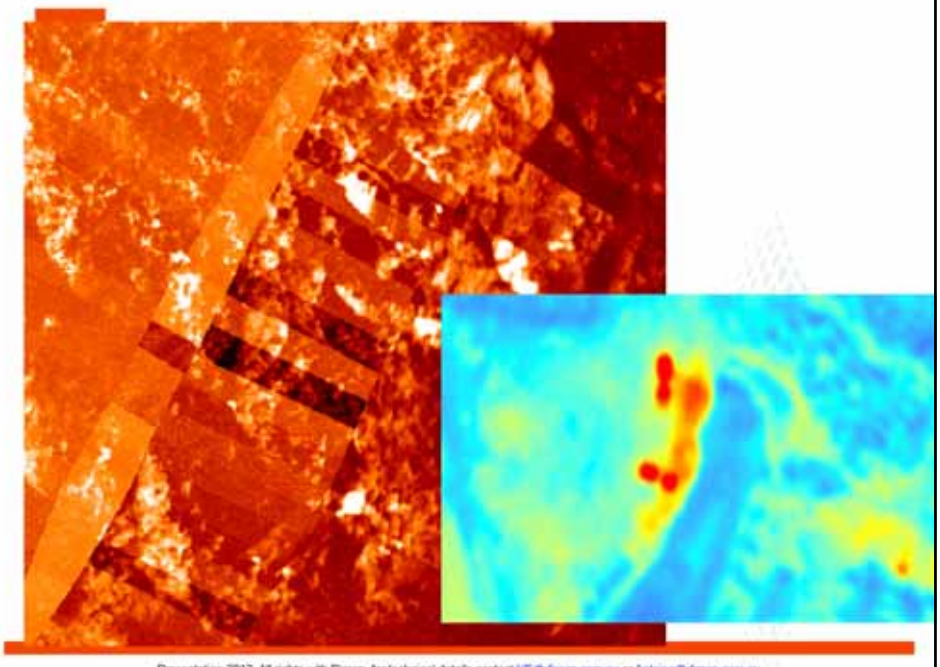
- Topographic mapping of the terrain using a high power Lidar system
  - Lidar in IR in 1064nm, class 3 eyesafe
  - Flying height: 1500m
  - Swath width (overlap 70%): 1000m
  - Point densities: 8 per sqm for topography
- Productivity: approx. 30 to 50 sqkm/flight hour





Verification of thermal properties of the fault line

- Usage of the thermal hyperspectral sensor
  - Spectral resolution: brightness temperature function with correction of the emissivity
  - Spatial resolution 2m, thermal 0.1K corrected
- Data fusion with Lidar for “destriping” of vegetation

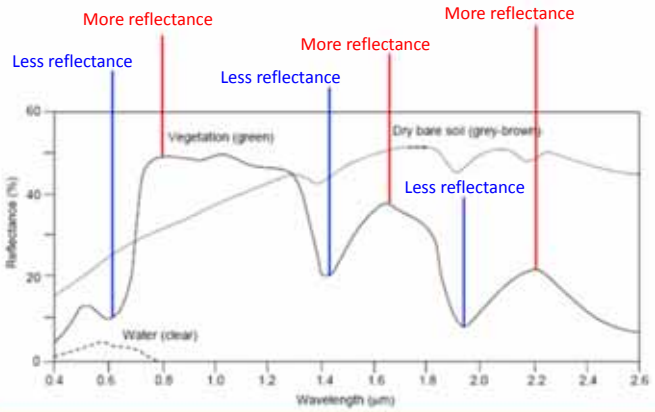


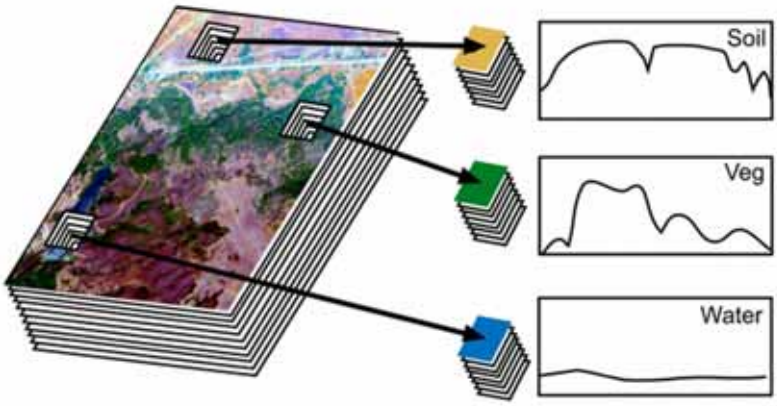
Mapping of clay minerals

- Usage of Hyperspectral VNIR and SWIR into the solution for mapping of land vegetation, soils, detailed land use, forestry and agricultural parameters, geotechnical facts, pollution on land
  - Flying height: still 600m
  - Same flight as dual Lidar solution
  - Spectral resolution: 416 bands in 400 to 2500nm
  - Spatial resolution: 1m

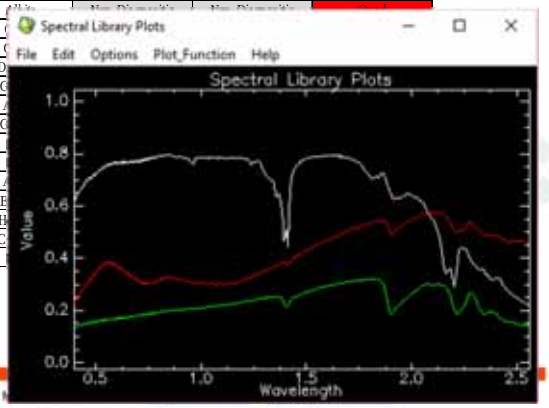
General concept: Reflectance

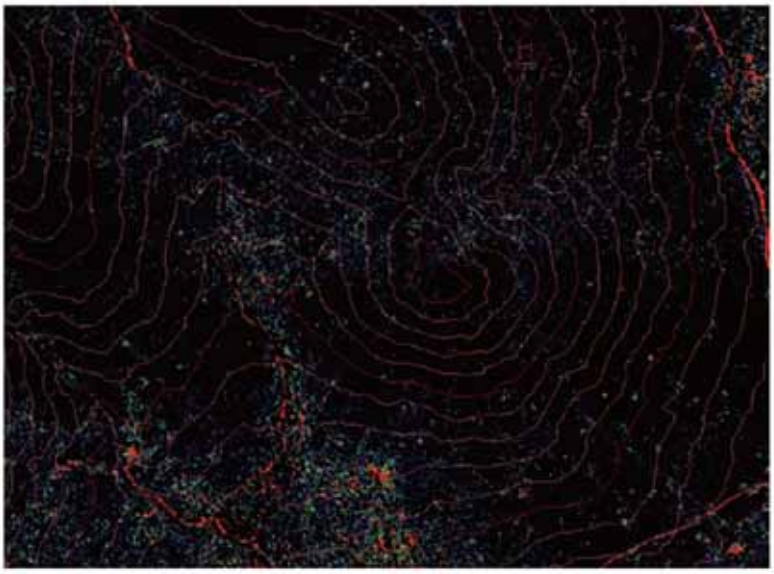
- Material absorbs and reflect specific wavelength of light
- Identify materials by their spectral signature





Type	Silicate Structure	Mineral Group	Example	VISNIR Response	SWIR Response	TIR Response
Silicates	Inosilicates	Amphibole	Actinolite	Non-Diagnositic	Good	Moderate
		Pyroxene	Diopside	Good	Moderate	Good
	Cyclosilicates	Tourmaline	Elbaite	Non-Diagnositic	Good	Good
	Nesosilicates	Garnet	Grossular	Moderate	Non-Diagnositic	Moderate
		Olivine	Forsterite	Good	Non-Diagnositic	Moderate
	Sorosilicates	Epidote	Epidote	Non-Diagnositic	Good	Moderate
	Phyllosilicates	Mica	Muscovite	Non-Diagnositic	Good	Moderate
		Chlorite	Clinochlore	Non-Diagnositic	Good	Moderate
		Clay Minerals	Illite	Non-Diagnositic	Good	Good
			Kaolinite	Non-Diagnositic	Good	Good
	Tectosilicates	Feldspar	Orthoclase	Non-Diagnositic	Non-Diagnositic	Good
		Silica				
Non-Silicates	Carbonates	Calcite				
		Dolomite				
	Hydroxides					
	Sulphates	Alunite				
	Borates					
		Chlorides				
		Apatite				
	Hydrocarbons					
	Oxides	Hematite				
		Spinel				
	Sulphides					

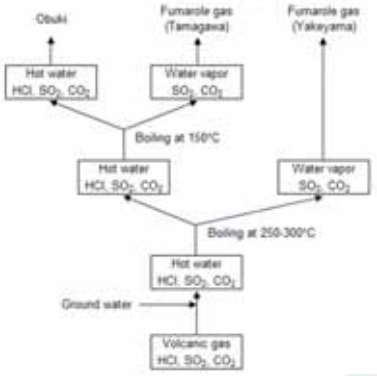


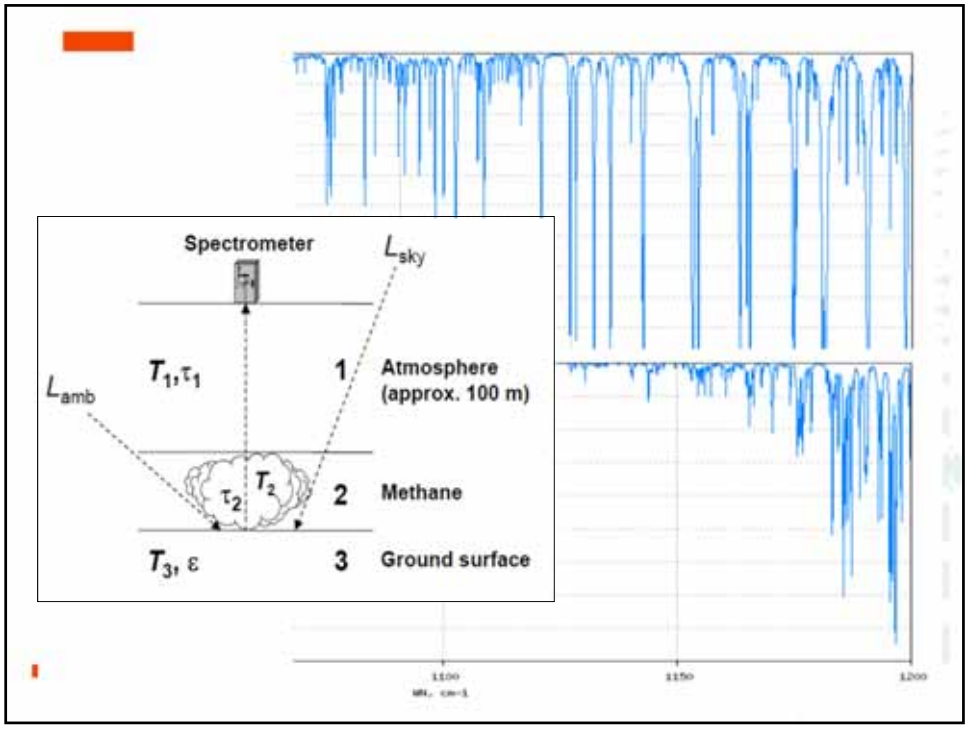


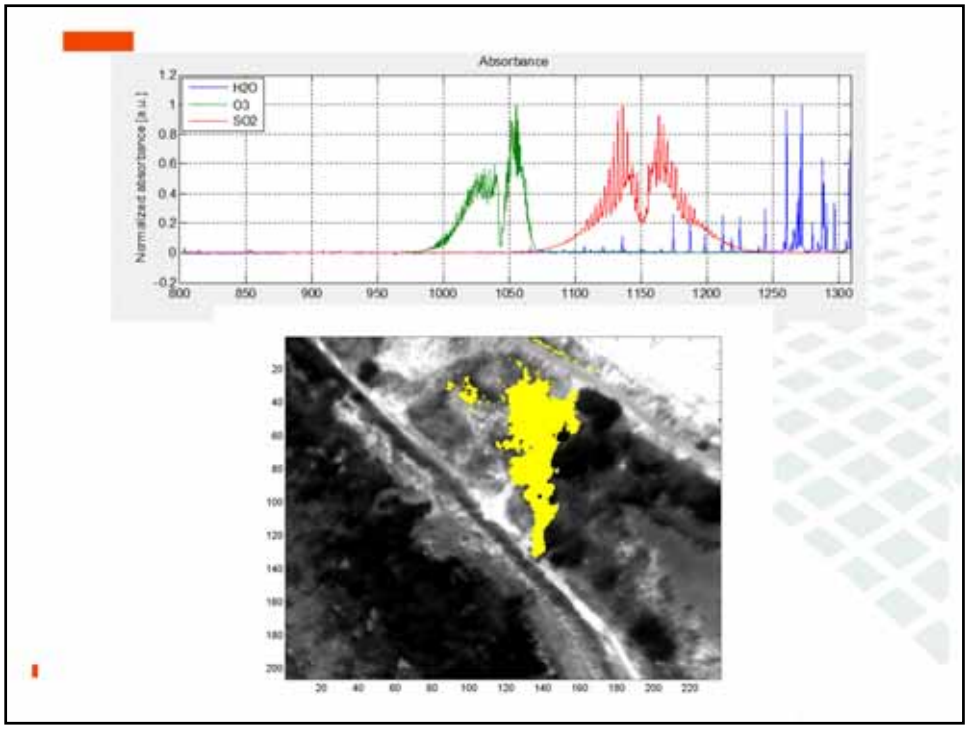
Mapping of gas output on the fault lines

- Integration of thermal hyperspectral for gas analysis
  - Spectral resolution: 130 bands in 7600 to 11800nm
  - Thermal resolution: better 0.018K
  - Spatial resolution: 2m
- Support of VNIR/SWIR Hyperspectral for indirect detection of gas related changes on the vegetation

- CO, SOx and H2S are the main gases around geothermal sources
- The mapping of this gases is used to find even non airborne visible fumaroles
- The amount of gases and mixture provides an indication of type of the prospect

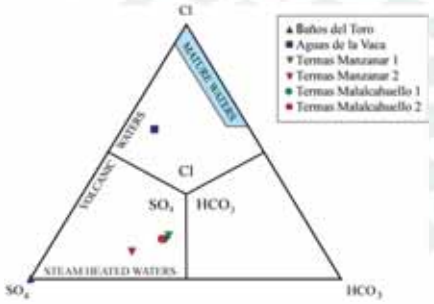



Spectrometer
L_{sky}
L_{amb}
T_1, τ_1
1
Atmosphere
(approx. 100 m)
τ_2
T_2
2
Methane
T_3, ε
3
Ground surface
1100
1150
1200

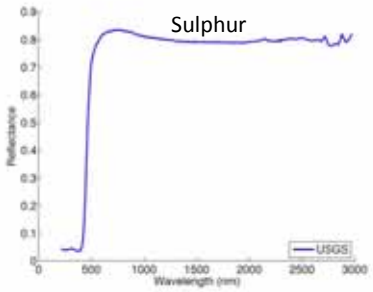

Absorbance
H2O
O3
SO2
Normalized absorbance [a.u.]
800
850
900
950
1000
1050
1100
1150
1200
1250
1300

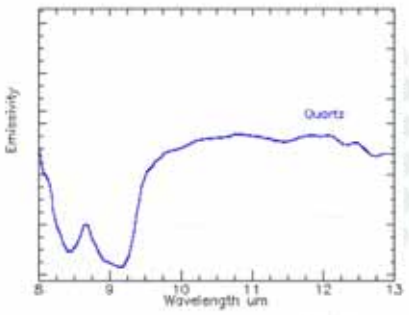
Further effects to look at

- Fumaroles, hot springs and the surrounding
  - Differences in the Chemistry in geothermal and non-geothermal water – not direct map able
  - Only detectable on temperature
  - Usage of sediments around the water bodies

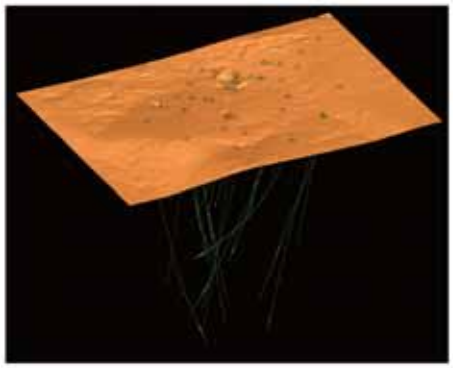


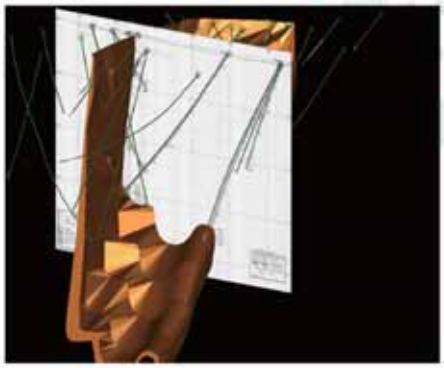
- Sulphur deposits in SWIR
- Silicates / Quartz structures on the shores in LWIR





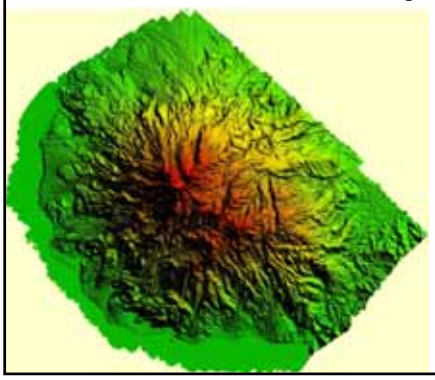
The next steps on the way to a geothermal power production





Thanks for your attention

and please feel free to ask any question



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