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The Limitations of the Gravity Technique when Investigating a Possible Ground Zero

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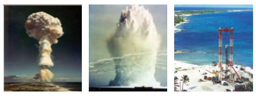
INTRODUCTION

Three possible nuclear test scenarios can be employed: Atmospheric, Marine and Underground. If nuclear tests are performed in the Atmospheric or Marine environments, it is very difficult to hide. Countries that consider to do a secret nuclear test will most probably choose an underground location.

The suitability of the underground location will depend on the geology. Hard rock geology with a high density is a prerequisite to perform such tests to contain the explosion. Suitable mafic geology include basalt (2.55 g/cm3) and granite (2.75 g/cm3). Suitable sedimentary geology include massive limestone (2.65 g/cm3) and sandstone (2.3 g/cm3).

POSSIBLE TYPES OF TEST SCENARIOS



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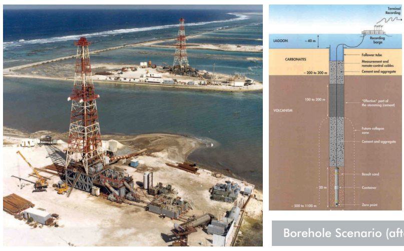
1. Atmospheric Scenario
2. Marine Scenario
3. Underground Scenario



Borehole Scenario (after Le Garrec, 2004)

POSSIBLE UNDERGROUND TEST SCENARIOS

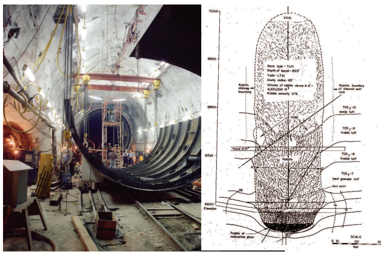
The first option is the Borehole Scenario:

- Suitable Geology – Good Density Contrast.
- Total depth of Borehole ~1000m.
- Original Borehole Diameter ~15m.
- Collapse Zone around hole after explosion ~20m radius.
- Total Height of explosion cavity ~ 100m.

POSSIBLE UNDERGROUND TEST SCENARIOS

The second option is the mining Scenario:

- Suitable Geology – Good Density Contrast.
- Total Depth of shaft ~1000m.
- Test Chamber Diameter ~40m.
- Collapse Zone around cavity after explosion ~20m radius.
- Total Height of explosion cavity ~ 120m.
- Rubble Porosity ~ 21%.



Mining Scenario (after Le Garrec, 2004)

GEOPHYSICAL CONTINUATION PHASE TECHNIQUES FOR DEEPER ARTEFACT DETECTION

The Micro Gravity Technique measures the variations in the gravity acceleration (g). Variations in g are due to various factors, of which the variations in density and the distance from the target are the most important. Cavities like sinkholes or a nuclear test chamber, represents a lack of mass and lowers the density. The result is a lowering in the gravitational acceleration (g). Modern Gravity meters have the ability to measure variations of 10-7 in g. It is thus possible to detect voids below the surface. This is possible only with very experienced operators. It is essential that the elevation and the latitude position of the measuring station is measured accurately (to be smaller than 10mm). It can also only be achieved with very experienced operators. Experienced operators could achieve a survey resolution of 0.03 mgal, where very experienced operators could achieve a survey resolution of 0.01mgal.

Current experience show that the best production rate and most accurate positioning is achieved with a Total Station. A Total Station use trigonometry beacons, infra red beams and mirrors to accurately measure the positions and elevation of a measuring station. This accuracy is currently very difficult to achieve with GPS, even with dual frequency differential systems. This is due to spheroid distortions if the survey area is large and time constraints when a measuring station is occupied.

The gravity technique is the most successful technique to detect cavities, such as sinkholes. Suitable geology with a large density contrast between the cavity and the host rock makes it easier to detect. As a bonus, relatively large cavities are formed during an explosion test. Large infrastructure developments are also necessary to perform the test. Collapse of the surrounding host rock and fracturing after the explosion also takes place.

MICRO GRAVITY TECHNIQUE INSTRUMENTATION

Gravity Meter

Total Station

Differential GPS

THEORETICAL FORWARD MODELLING OF GRAVITY RESPONSES

Physical modelling and numerical modelling complement each other (Fourie, C.J.S., 1995). The theoretical gravity responses were modelled for various scenarios, in different geological settings. These were granite and sandstone environments. Modelled responses were calculated for the explosion cavities only (worst case scenario), because the other infrastructure development around the cavities can vary. This include long access tunnels and deep boreholes. Not all possible parameters were included during the modelling to keep models as simple as possible. These modelling results is an attempt show what can be expected from the Gravity Technique. The Interpex Magix software package were used for borehole and mining cases under the following conditions:

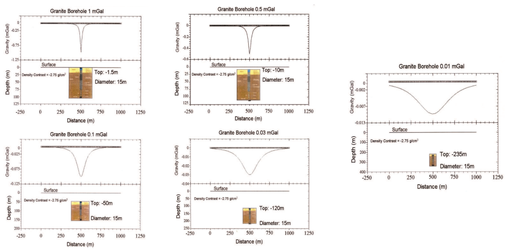
- Before Detonation.
- After Detonation.

The "After Detonation" cases are the simulations that will be the closest to the real cases, because fracturing occur that will increase the chances of detecting the cavity. Five modelled results were calculated for each possible scenario. Special attention should be given to the "DEPTH OF DETECTION" between the 0.03 and 0.01 mgal resolution of an experienced and very experienced survey team. Only the granite visual results are shown, but the sandstone results are included in the table. The modelled results show that the deeper the cavities produces a smaller anomaly and is thus more difficult to detect.

CTBTO PREPARATORY COMMISSION preparatory commission for the comprehensive nuclear-test-ban treaty organization

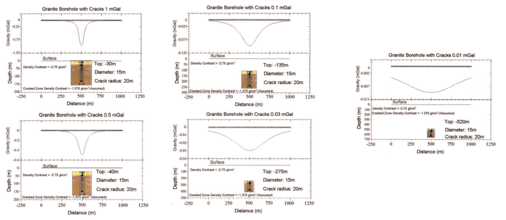
GOLD FIELDS

MODELLING RESULTS – BOREHOLE IN GRANITE BEFORE DETONATION



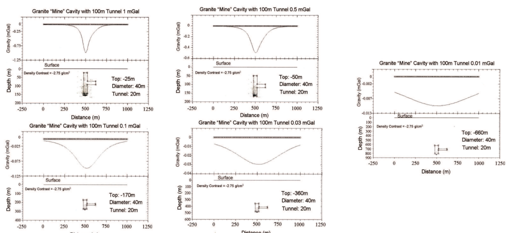
- Explosion Cavity is 100m in height.
- Measurements stay constant, even for deeper models.

MODELLING RESULTS – BOREHOLE IN GRANITE AFTER DETONATION



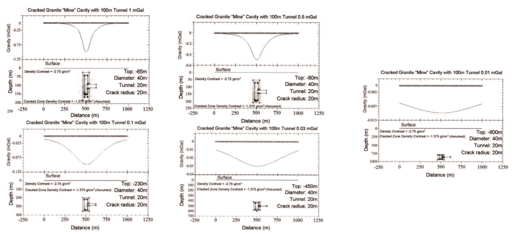
- Explosion Cavity is 100m in height.
- Measurements stay constant, even for deeper models.

MODELLING RESULTS – GRANITE MINE TUNNEL BEFORE DETONATION



- Explosion Cavity is 120m in height.
- Access Tunnel is 100m.
- Measurements stay constant, even for deeper models.

MODELLING RESULTS – GRANITE MINE TUNNEL AFTER DETONATION



- Explosion Cavity is 120m in height.
- Access Tunnel is 100m.
- Measurements stay constant, even for deeper models.

MODELLING RESULTS – SUMMARY

Granite			Sandstone		
Borehole	Before Detonation	After Detonation (Cracks)	Borehole	Before Detonation	After Detonation (Cracks)
Gravity Value	Depth(m)	Depth(m)	Gravity Value	Depth(m)	Depth(m)
-1mgal	-1.5	-30	-1mgal	0	-25
-0.5mgal	-10	-40	-0.5mgal	-7.5	-35
-0.1mgal	-50	-135	-0.1mgal	-40	-120
-0.03mgal	-120	-275	-0.03mgal	-105	-255
-0.01mgal	-235	-520	-0.01mgal	-210	-480
Mine with tunnel 100m	Before Detonation	After Detonation (Cracks)	Mine with tunnel 100m	Before Detonation	After Detonation (Cracks)
Gravity Value	Depth(m)	Depth(m)	Gravity Value	Depth(m)	Depth(m)
-1mgal	-25	-45	-1mgal	-18	-37
-0.5mgal	-50	-80	-0.5mgal	-40	-65
-0.1mgal	-170	-230	-0.1mgal	-150	-200
-0.03mgal	-360	-450	-0.03mgal	-325	-410
-0.01mgal	-660	-800	-0.01mgal	-600	-735
Density of Granite	2.75 g/cm^3		Density of Sandstone	2.30 g/cm^3	
Density of Crack zone	1.375 g/cm^3		Density of Crack zone	1.15 g/cm^3	

CONCLUSIONS

- Easier to detect Cavities after detonation.
- Easier to detect "Mining" Cavities than Boreholes Cavities.
- Effects of added infrastructure to perform the test was not incorporated in the modelling for worst case scenarios (due to large variations).
- Larger density contrast of geology increases the possibility to detect Cavities.
- It is more difficult to detect deeper Cavities (Fourie, C.J.S.,2008).
- Maximum detection depth of Cavities are between 800 to 1000m, depending on the size of the cavity and experience of the survey team.
- Less experienced survey team will be less successful in detecting deeper Cavities.
- Actual tests with infrastructure (complete Borehole or access tunnels) towards explosion Cavity will make the ground zero easier to detect.

RECOMMENDATIONS

- The Micro Gravity Technique should be used at a possible ground zero because it is one of the most appropriate Geophysical Methods to detect cavities, and should produce positive results.
- It should only be used by an experienced team to guarantee credible results.

REFERENCES

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4. Le Garrec, S., 2004, CTBTO Induction Notes.