

Briefing Note on Reactive Ground

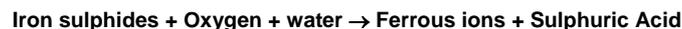
Background

Reactive ground is a term used in the mining industry to describe ground in which the reaction between sulphides (especially iron and copper sulphides) contained in rock and the ammonium nitrate contained in explosives may take place.

The reaction of ammonium nitrate with sulphide-containing minerals is an auto-catalysed process which can, after some induction time, lead to a runaway exothermic decomposition even if the starting temperature of the mixture is around an ambient temperature of 20°C. The reaction scheme developed over the last 30 years of research by groups such as the US Bureau of Mines (USBM) and others is described in a simplified form below.

Chemistry

Natural oxidative weathering of iron sulphides such as pyrites by atmospheric oxygen generates solutions of ferrous ions and acid. This process occurs whenever the sulphides are exposed to air along cracks, in drilled holes, in the muck pile after blasting, on pit walls and in old stopes. No nitrates are required for this to occur.



This reaction is exothermic and can for particularly reactive ores, lead to hot blastholes. This temperature increase can be as little as 2°C or as much as several hundred degrees.

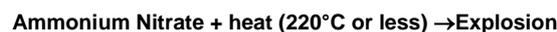
On contact with ammonium nitrate, the ferrous and acid species from weathering can begin to catalyse the breakdown of nitrate. The breakdown process is autocatalytic in that it generates its own catalysts as it proceeds.



The nitric oxide and ferric ions produced in this stage react with more pyrites, generating more ferrous ions and sulphuric acid.



Although these reactions are exothermic, their rate may be initially so slow that little or no temperature rise is detectable. This is due to the concentration of catalytic species building up to some critical level. The time taken for this to occur is often referred to as the induction period. When sufficient catalysing species have built up, the reaction rate increases sharply and the heat generated causes the temperature to become so high that a rapid, potentially violent decomposition of the remaining ammonium nitrate is inevitable.



Some Known Incidents

Mt. Isa	1960's	- Holes in 500 orebody became incandescent on contact with AN from ANFO.
Russia	1968	- Gaiskii Combine copper, spontaneous detonation with AN explosives.
BHP Newman	1983	- A hole loaded with ANFO detonated prematurely while shot crew were still on the shot.
BHP Newman	1987	- A hole which was lined and loaded with ANFO detonated when the hole liner split.
USA	1989	- Battle Mountain Gold and 1991 Paradise Peak Gold premature detonations with ANFO.
Mt. Lyell	1989	- Premature detonation of AN emulsion within 10 hours of loading.
Canada	1989	- Faro gold mine, detonations with AN emulsion.
	1990	



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Sth. Africa	1990	- Rosario Dominicana mine, heavy ANFO caused burning and premature detonation.
Mt. Leyshon	1992	- Emulsion in a shot which had been sleeping for several months detonated.
Collinsville Coal	1995	- Holes containing a TES emulsion (HEF) caught fire.
Collinsville Coal	1998	- A hole loaded with Sawdust/ANFO detonated prematurely.
Sons of Gwalia	1998	- Several holes at Jacoletti pit started smoking within 20 minutes of being loaded with heavy ANFO.
Century Zinc	1998	- AN spilt on the bench started to burn several days after the shot was fired.
Other		- Oman and Cyprus details unknown.

Factors Affecting Reactivity

Mixtures of all iron sulphide bearing minerals and nitrates are thermodynamically unstable and may be reactive. The rate of the reaction is dependent upon the type of mineral, the level of oxidation, particle size of the mineral and thermal conductivity of the surrounding rock, porosity of the crystal structure, surface area of the crystals and the amount of water and oxygen available. It has so far proven impossible to predict which deposits will be sufficiently reactive to present problems in blasting since none of the above factors correlate reliably enough with reactivity.

If a deposit is reactive, the amount of heat potentially generated will increase with sulphide content, simply because this provides more fuel for the reaction.

Indicators of Potential Reactivity

Some of the indicators of potential reactivity include:

- The presence of sulphur dioxide;
- Faster than expected rusting of rock bolts etc, because of the sulphuric acid;
- Warmer than usual air rising from blastholes, due to the oxidation of the rocks;
- Acidic ground water due to the sulphuric acid.

Note that none of the above are in any way perfect predictors of reactivity.

Testing for Reactivity

The recommended method for determining if iron sulphide bearing minerals are reactive is by chemical compatibility testing. Orica can perform a direct compatibility test between the rock and ammonium nitrate. Alternatively, laboratory testing companies can perform a DTA (differential thermal analysis) test for compatibility, although Orica believes this method is less informative due to the very small sample size and other technical considerations.

Samples of minerals for testing must be selected with advice from the mine geologist. The recommended procedure for doing this is described below.



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Sampling Rocks for Reactivity

The aim of all reactive ground sampling is to collect samples containing iron sulphides. In the first instance, a judgmental or authoritative method for collecting rock samples can be used. This is a look at the "worst-case" samples present in the mine based on the local geologist's knowledge of the pit. Typically, this will involve sampling black shale or massive sulphide units.

Only samples which are high in iron sulphides, or are pyritic in nature, need to be collected at this stage. If there are large amounts of this type of rock present, then the pit geologist can advise further on which samples are likely to contain the highest amounts of iron sulphides.

This investigation should result in at least 2-3 samples but no more than, say, 10.

The exact location of where the sample came from must be identified by the geologist and recorded, as this will aid in the systematic sampling which will occur later if the samples prove reactive.

It is not recommended that the samples be drill cuttings for the purpose of this investigation, as this can potentially dilute any worst-case sample which might exist. Care should be taken to ensure that the sample taken has not fallen from a higher point or been moved from a different location. Samples picked off walls are useful for this investigation.

Each sample should be approximately 0.5 - 1.0 kg and individually packaged in a plastic bag. The analysis of the samples should be co-ordinated through your Orica Account Manager or Contract Manager, who will put you in contact with the regional Technical Superintendent.

This method of sampling and testing will provide information on whether the pit does in fact contain reactive ground.

Subsequent Action

If the reactivity result is negative, then some ongoing sampling and testing may be required as different geology units are encountered or other incidents cause mine personnel to believe they have a reactive ground issue.

If the reactivity result is positive, then Orica recommends that only explosive products containing an inhibitor are loaded into that geology type. It is also recommended that this type of product be introduced immediately. Barriers which prevent rock from contacting the ammonium nitrate have been used in the past for reactive ground applications. For reactive ground applications, the use of blast-hole liners (with uninhibited bulk explosives) and uninhibited packaged products should be discouraged unless deemed suitable through a detailed risk analysis.

The extent of reactivity is often then determined if deemed necessary. This will typically involve looking at other geological units within the mine. This sampling must also be done in consultation with the mine geologist. A systematic investigation can be used for this type of sampling and should be based on coverage of the geological domains rather than levels of sulphide content

The results of this program can then be used to formulate a long term strategy on how to effectively manage the risk from reactive ground at a particular site to ensure the safety of all personnel.



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Use of Inhibited Products

An analysis can be performed to determine the level of inhibitor required to quench the reaction for 12 hours. Orica has a comprehensive range of products to satisfy customers with reactive ground. It includes bulk wet hole and dry-hole products for the open-cut market, and bulk and packaged explosives for the underground market. Talk to your Orica Account Manager or Contract Manager about the product best suited to your mine.

The inhibitor is added to the emulsion phase and slows down the reaction, but does not prevent it. Consequently, a 12 hour sleep time maximum is recommended. Sleep times greater than this can be authorised, but are only recommended if additional extended lab testing has been completed.

As the presence of heat in blastholes can cause the reaction to occur faster, and the initial oxidation (weathering) reaction can produce heat, it is recommended that temperature logging of blastholes is performed in reactive areas of the mine. Once it is established that a certain geological unit does not show any evidence of warming before explosives are added, then temperature logging can cease. However, if the holes do show that the oxidation reaction is occurring rapidly and producing heat, then no holes over 50°C can be loaded with conventional explosives and alternative supplies need to be discussed with your Orica Account Manager or Contract Manager.

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References

1. John Alfred Rumball, **The Interaction of Partially Weathered Sulphides in the Mt McRae Shale Formation with Ammonium Nitrate**, PhD Thesis, Murdoch University, 1991
2. **Australian Standard AS2187**, Part 2 - 1993, "Use of Explosives"
3. Gwyn Harries et al, **The Reaction of Ammonium Nitrate with Black Pyritic Shale at Mt Whaleback**, The AusIMM/IE Aust Newman Combined Group, Large Open Pit Mining Conference, Oct 1986
4. Yael Miron, **Blasting Hazards of Gold Mining in Sulfide-Bearing Ore Bodies**, Information Circular 9335, US Department of the Interior and US Bureau of Mines, 1992

