

TO: The Hon Paul Holloway MLC, Government of South Australia

FROM: Edward Cranswick

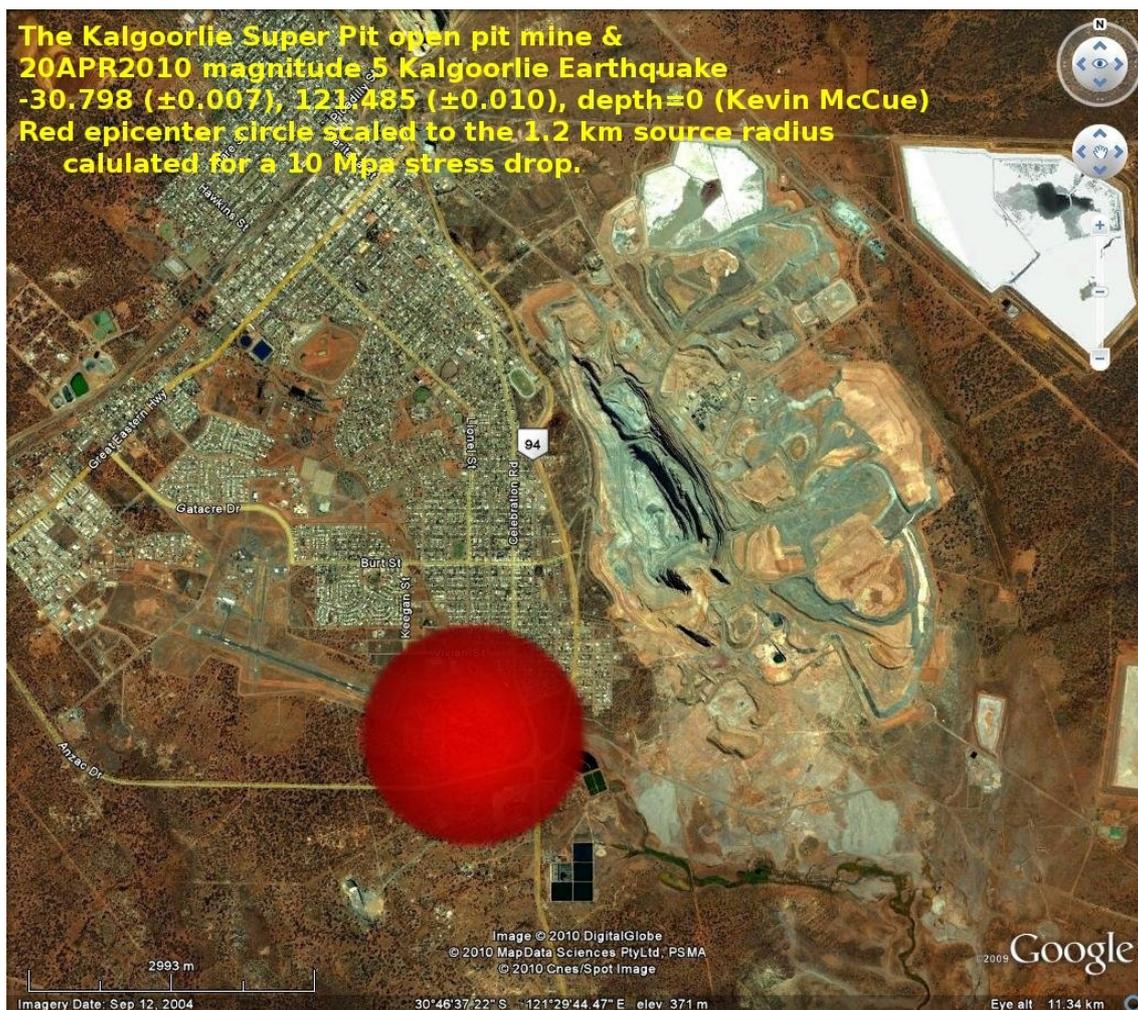
CC: DPLG:Public Submissions

CC: Federal Environment Minister Peter Garrett, and others

DATE: Tuesday 25MAY2010

SUBJECT: The Kalgoorlie Earthquake and the Proposed Olympic Dam Mine Expansion

BHP Billiton has proposed to dig the largest open pit mine on the Earth at Olympic Dam, 4.1 km long, 3.5 km wide, 1 km deep. As a [geophysicist who investigated earthquakes for the US Geological Survey for 22 years](#) [1], I strongly criticised [BHP's Olympic Dam Expansion Draft Environmental Impact Statement 2009 \(ODXdEIS\)](#) [2] because it omitted consideration of seismicity, i.e., rockbursts or earthquakes, caused by open pit mining, despite the fact that seismic hazard is well-known in the Australian mining industry (Hudyma et al. 2003 [3], [Kalgoorlie Consolidated Gold Mines \(KCGM\)](#) [4]). The recent Kalgoorlie Earthquake emphasises the probability and consequences of these seismic events as mines grow larger and deeper – the ODXdEIS needs to be re-evaluated because it does not address this issue at all. I discuss the connection between mining and seismicity and how it is obscured in Australia, particularly the seismic hazard of the Olympic Dam mine, and I make recommendations about these matters.



The 20APR2010 magnitude 5 Kalgoorlie Earthquake occurred in close proximity to the Kalgoorlie Super Pit mine ([see figure above](#)) [5]. This seismic event is further evidence of the potential of open pit mines to cause earthquakes in stable continental regions (SCR) such as Australia as discussed in the paper, *Mashers Fault and the Seismicity Anticipated to be Stimulated by the Proposed Open Pit Mine at Olympic Dam* (Cranswick 2009) [6], I presented at the [Australian Earthquake Engineering Society \(AEES\) in December 2009 in Newcastle, NSW](#) [7].

On 04DEC2009, I emailed you a pre-print of my paper that you kindly acknowledged in a letter to me dated 15DEC2009 in which you noted that one of your departments, Primary Industries and Resources (PIRSA), would have a representative at the AEES conference. Previously, on 07AUG2009, I had made a Public Submission to your office about earthquake hazard&risk in response to the ODXdEIS, *Seismicity anticipated to be stimulated by BHP's proposed open pit mine at Olympic Dam* [8].

The [Kalgoorlie Super Pit](#) [9], with the dimensions 4 x 1.5 x 0.65 km (2.5 x 1.3 x 0.2 km, 12SEP2004, [Google Maps](#) [10]), is the largest open pit mine in Australia, and according to the earthquake location of Kevin McCue (personal communication 2010), the Kalgoorlie Earthquake occurred near the Earth's surface, i.e., at zero depth, about 2-3 km south west of the pit. A former seismologist with Geoscience Australia, Victor Dent, said, ["I think the stress was changed by the digging of the Super Pit and that predisposed the area to an earthquake."](#) [11].

The relationship between mining, stress, and rockbursts (a rock burst is "the significant damage caused to underground excavations by a seismic event") in mines has been long recognised by mining engineers – indeed, it is one of their principal concerns. Furthermore, Kalgoorlie has a long history of seismic activity induced by mining – Ortlepp (2005) [12], a rock engineer for 33 years in the deep mines of South Africa and organiser of the series of international symposia founded in 1982, [Rockbursts and Seismicity in Mines \(RaSiM\)](#), discusses this seismic hazard:

"In Australia, rockbursting was first experienced as a significant but relatively infrequent problem in the Kalgoorlie district in the early part of the last [20th] century. During the last decade of the century [1990s], as the extraction of the deepest massive orebodies of the Mount Charlotte mine peaked, several very large mining-induced tremors were experienced. Six seismic events between ML 2.5 and ML 4.3 (Richter scale) were recorded"

Based on the 72 mines that responded to their 148-question survey circulated to 135 mines in 18 countries, Hudyma and Potvin (2004) [13] concluded: "The incidence of high seismic hazard appears to be somewhat greater in western Australia compared with underground, mechanized, hardrock mines elsewhere in the world."

There are reports from other stable continental regions of earthquakes triggered/induced by mines or other human activities (trigger: the fault is already near the breaking point and needs only a small stress change to fail). In the the Kaap-Vaal craton in South Africa, only 8 of the 378 magnitude 3.5-4 earthquakes recorded in 50 years were "natural" i.e., more than 30 km away from mining activity (Ortlepp 2005); hence, 98% were near mines. In northeastern United States, one third of the earthquakes greater than magnitude 3 during the period 1971-2003 were "human triggered", mostly by quarries or fluid injection (Seeber et al. 2004) [14]. By contrast, the Australian story seems to be that earthquakes can happen anywhere in Australia except at mines, and when they do happen at mines, it's just coincidence – notable exceptions to this story are seismological papers about mining-induced seismicity, e.g., McKavanagh et al. (1995) [15] and Gibson and Peck (2006) [16].

There has often been an implicit, if not intentional, censoring of Australian earthquake catalogues (lists of earthquakes and their corresponding source parameters, i.e., time, location, depth, magnitude) compiled by regional and national seismograph networks because seismic events in the vicinity of mines are frequently discarded under the assumption that these events are explosions. However, comparison with the South African data cited above suggests that some of these discarded events may have been earthquakes, either "natural" or those triggered/induced by the mining process – important information has been lost. Some of these events may have been very well recorded by microseismic monitoring systems within mines but that information can be difficult to access – [BHP Billiton at Olympic Dam is exempt from Freedom of Information Act 1991](#) (Burdon 2006) [17].

Cranswick (2009) discussed three earthquakes triggered by open pit mining, and now there has been another even larger earthquake at Kalgoorlie within about a pit's length of the Super Pit – maybe it's just coincidence ... the KCGM mine management might know – do a search for 'earthquake' on their website <http://www.superpit.com.au/>.

The proposed 4.1 x 3.4 x 1 km open pit at Olympic Dam would be much deeper than the Super Pit is now and several times the volume, and it would be excavated from rock subjected to high horizontal EW compressive stresses (~43 MPa at 1 km depth, Bungler et al. 2008 [18]). Traditionally, underground mines are deeper, and therefore, more seismically hazardous than shallow open pits, but the proposed pit at Olympic Dam will be as deep as the underground mine it replaces. Based on the dimensions of the open pit, the results of McGarr et al. (2002) [19] suggest an earthquake of maximum magnitude 4-6 could occur.

The 35-km-long, steeply dipping Mashers Fault passes through the middle of the Olympic Dam ore body that is to be mined – that fault length implies an earthquake of maximum magnitude about 7 (Wells and Coppersmith 1994) [20]. Cranswick (2009) discusses Australian earthquakes in the magnitude range 6-7 during the last half century that produced fault scarps more than 1 m high and more than 10 km long. At Olympic Dam, such scarps and the strong groundmotions generated by the corresponding earthquakes could severely damage the 9 Tailings Storage Facilities (TSFs, i.e., square tailings dams, 2 x 2 km, and 65 m high) that will be built to contain gigatons of hazardous tailings.

Bores in the 100-500-m-wide Mashers Fault zone near the mine have high fluid flows (ODXdEIS), and Ito and Zoback (2000) [21] find that, "critically-stressed faults in the crust are also the most permeable faults"; hence, Mashers Fault may be critically stressed. More recently at Olympic Dam, ["damage from a plummeting ore skip in its main shaft \[06OCT2009\] is expected to reduce capacity to about 20 per cent for up to six months"](#) ([The Australian 21OCT2009](#)) [22], but no information about the cause of the accident has been released – the main shaft is ~2 km north-northwest of the surface expression of the Mashers Fault which dips towards it. Was the accident preceded by a seismic event?

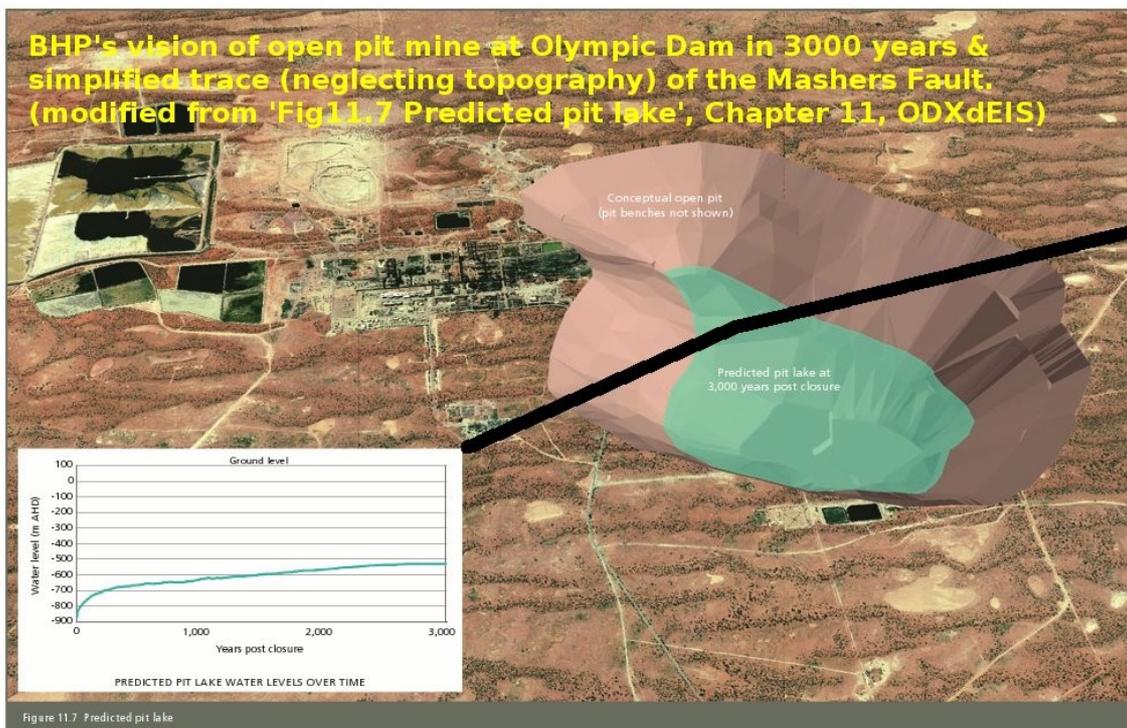
In their paper, *An Engineering Approach to Seismic Risk Management in Hardrock Mines*, Hudyma and Potvin (2009) [23] state:

"The problem of mining-induced seismicity in hardrock mines has become significant as underground mines from around the world are pushing production to deeper levels. At many mines, the risk associated with large seismic events and rockburst damage must be managed to ensure the safety of mine workers and minimise production losses."

Ortlepp (2005) concludes: "It is to be hoped that large mining corporations and mine owners will also see the light and realise that it is ultimately in the best interests of all the stakeholders that the spectre of the rockburst hazard must be further exposed and eventually eliminated."

So here's the picture – on the surface, mining management & seismologists are not talking about earthquakes & mining – meanwhile, down in the mine, seismologists and the rest of the shift are worrying about when the next rockburst will happen as management tells them to go deeper & deeper ...

It is absurd – irrational, unscrupulously & tragically dishonest and unprofessional – that the ODXdEIS for the proposed largest open pit mine on Earth does not address the principal hazard to digging that mine, triggered/induced seismicity and rockbursts. The latter term does not appear once in the 4,600 pages of the ODXdEIS and its appendices. This omission echoes the [Washington Post \(05MAY2010\) headline, "U.S. exempted BP's Gulf of Mexico drilling from environmental impact study"](#) [24], about the world's worst oil spill and environmental catastrophe. The ODXdEIS purports to predict the water depth in the open pit 3,000 years from now ([see figure below](#)) [25] but does not mention any earthquakes at the mine during that same period.



No decision should be made concerning the ODXdEIS until specific new investigations are undertaken at Olympic Dam and published – made available to the public – regarding the seismic hazard of proposed open pit and the seismotectonic potential of the Mashers Fault.

These investigations of the Mashers Fault and vicinity would be conducted by independent teams that each focused on one of the following tasks: paleoseismology, i.e., evidence of previous fault movement; a microearthquake survey done in conjunction with the existing mine-wide microseismic monitoring system; a search of regional & national seismograph network data to recover all records of seismic events near mines (within 30 km), identification of sources, i.e., blasts or earthquakes, confirmed by mine blasting records; geomechanical analysis of *in situ* stress, pore pressure, borehole data, etc., to estimate Coulomb stress change (King et al. 1994) [26] on the

Mashers Fault in response to excavation of the open pit; geophysical analysis of gravity & magnetics to determine regional structure related to Mashers Fault.

An independent group of mining geologists, geomechanical engineers and mining seismologists would integrate the reports from the teams and write an overview, but all reports would be released in full as appendices. Much of this work has undoubtedly already been done – it needs to be released to the public and made available from a SA government website.

The majority of Australia's foreign exchange comes from mining, and [mining is already the most hazardous industry in Australia](#) [27]. As mining activity increases, seismic activity increases, and the amount of toxic tailings from the mines that must be safely contained increases – both seismic hazard & risk increase. Following the recent example, "[U.S. to Split Up Agency Policing the Oil Industry](#)" ([New York Times 11MAY2010](#)) [28], the responsibilities to promote and to regulate mining, both now done by the one South Australian government department, PIRSA, should be divided between two independent departments.

Edward Cranswick
12 Bowillia Ave
Hawthorn, SA 5062
TEL: 08 8271 1309
email: e_cranswick@yahoo.com

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