The Kalgoorlie Earthquake of 20 April 2010 and its Aftershock Sequence

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Abstract

On 20 April 2010 a magnitude 5.0 earthquake occurred under Boulder, Western Australia, at a depth of approximately 1.7 km. Five temporary recording systems were deployed around Kalgoorlie-Boulder which recorded aftershocks between 22 April and 8 June. The epicentre of the main shock was located by Geoscience Australia using data from the National Network and arrival times recorded by the mine monitoring networks in Boulder-Kalgoorlie and the Australian Centre for Geomechanics (ACG).

A total of 544 events were located by the temporary stations that Geoscience Australia deployed. Two groups of events are evident; one group at the southern end of Boulder is located around the epicentre of the main shock and a northern group is clustered around the Mount Charlotte Mine to the north of Boulder. The origin times of the events in the northern group coincide with routine blasting times at the mine. The aftershocks provide the opportunity to relate the seismic activity to known faults, and are a useful dataset for testing velocity models and to improve the discrimination of blasts from natural earthquakes.

Main-Shock

At 8.20 am (local time) on the 20th April 2010 an earthquake struck the Kalgoorlie-Boulder region. The earthquake was recorded across the Australian National Seismograph Network giving an initial location just south of Kalgoorlie. Geoscience Australia estimated the magnitude to be 5.0 which was reflected in the amount of significant building damage in the town (Figure 1). In the days following the earthquake Geoscience Australia sought to improve the accuracy of the earthquake epicentre by seeking further waveform and arrival data from existing local monitoring networks. The Australian Centre for Geomechanics (ACG) and Kalgoorlie Consolidated Gold Mines (KCGM) supplied this information for 15 seismic monitoring sites in the vicinity of the earthquake and this enabled a re-evaluation of the location of the epicentre. With the improved data coverage the epicentre was re-located towards the southern edge of Boulder (Figure 2).

Aftershock Deployment

Within 2 days of the main shock Geoscience Australia started to deploy temporary seismic stations around the area to capture the aftershock sequence. In less than 4 days 5

temporary aftershock kits were in operation and collecting valuable data. The aftershock kits are extremely portable cases containing a complete seismic station. This includes the sensor (Lennartz 3Dlite), data logger (Kelunji Echo), solar panel, all necessary cabling, tools and weather proofing materials. This has improved Geoscience Australia's ability to respond quickly to such events. The locations of the temporary stations (Figure 2) were chosen to maximise the azimuthal coverage of the aftershocks based on the epicentre of the main shock. The aftershock sequence following the April 20 event consisted of many relatively strong earthquakes that were widely felt in the Kalgoorlie area. 544 seismic events were recorded between 22 April and 8 June (Figure 2).

Aftershock Epicentres

The epicentres of the aftershocks extend 3km in a N-S direction. This provides an estimate of the overall rupture length of the mainshock and is consistent with a magnitude 5 earthquake. A large fault, shown in Figures 3 and 4 occurs just to the east of the mainshock and dips in the direction of Boulder. At a depth of 2-3km this fault intersects the mainshock location, making it a prime candidate for being the fault that ruptured during the earthquake. Assuming that the aftershocks occurred along the Boulder fault or offshoots of this fault, the data in Figure 3 shows the movement in depth and location of aftershocks over time, indicating that there was migration of slippage along the fault as stresses were released.

In Figure 2, aftershocks from the earthquake as well as a cluster of mining blasts in the northern area of the map can be seen. The concentration of events within an area 1.3 km x 0.6 km over the Mt Charlotte mine indicates that the spread of aftershock locations is real and not solely due to errors in location.

Aftershock Depths

A few conclusions can be drawn from the depth of aftershocks. The depth of the aftershocks does not exceed 4.5km. This indicates that the rupture of the mainshock most likely did not extend below this depth. The location of the aftershocks also varies with depth. The aftershocks at a depth of 1-2km occur over a smaller area than those of depth 0-1km. The same applies to those occurring at a depth of 2-3km in comparison to the shallower aftershocks. This may indicate that the deeper rupture was constrained to this area and rupture propagated to a greater extent nearer to the surface. The deeper aftershocks are also concentrated to the west of the Boulder Fault, reflecting the dip of the fault towards the west.

Velocity Model Comparison

The occurrence of so many aftershocks and blasts in one location along with the placement of the aftershock deployment allowed us to run a comparison between different velocity models in the area. All the aftershocks and blast recorded were located whenever possible using both IASPEI91 and WA2A velocity models. Overall, IASPEI91 epicentres had lower residuals, indicating the arrivals of seismic waves had a better fit to the IASPEI91 velocity model than the WA2A model. The data in Figure 5 show that the locations using the WA2A model have an overall spread away from the stations due to the higher velocities in the WA2A model compared to IASPEI91. This indicates that the velocity of seismic waves in the WA2A model is overestimated slightly in this area.

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Figures

Figure 1. Building damage caused by the 20th April earthquake

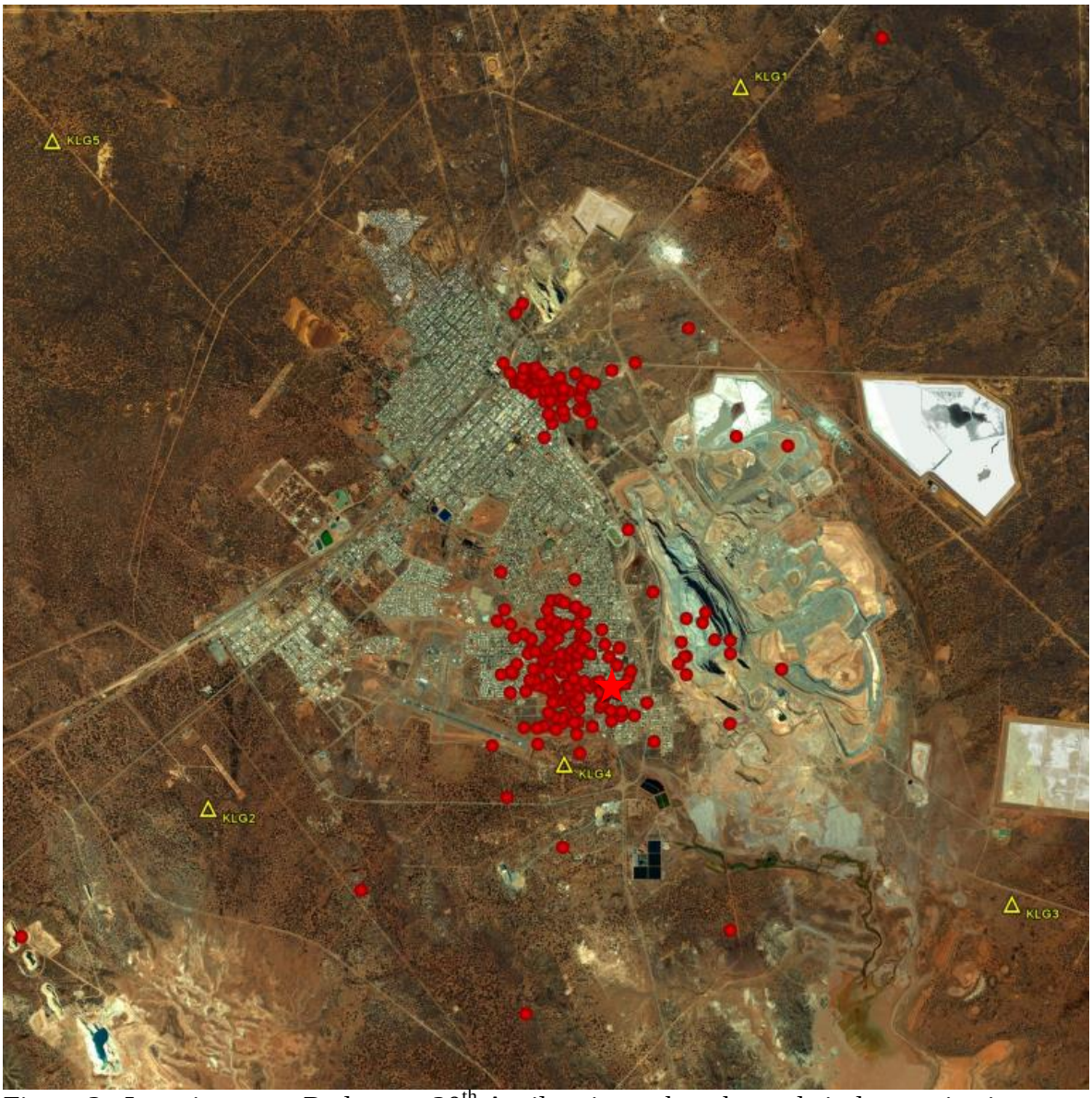

Figure 2. Location map: Red star = 20th April main earthquake; red circles = seismic events recorded from 22 April to 8 June; yellow triangles = temporary seismic stations

Figure 3. Aftershocks recorded in the first 6 days of the aftershock deployment, a) day 1, b) day 2, c) day 3, e) day 5, f) day 6. Red star = epicentre of mainshock. Yellow line = Boulder Fault

Figure 4. a) Aftershocks with depth 0-0.9km b) Aftershocks with depth 1-1.9km c) Aftershocks with depth 2-2.9km d) Aftershocks with depth 3km+, Red star = epicentre of mainshock.

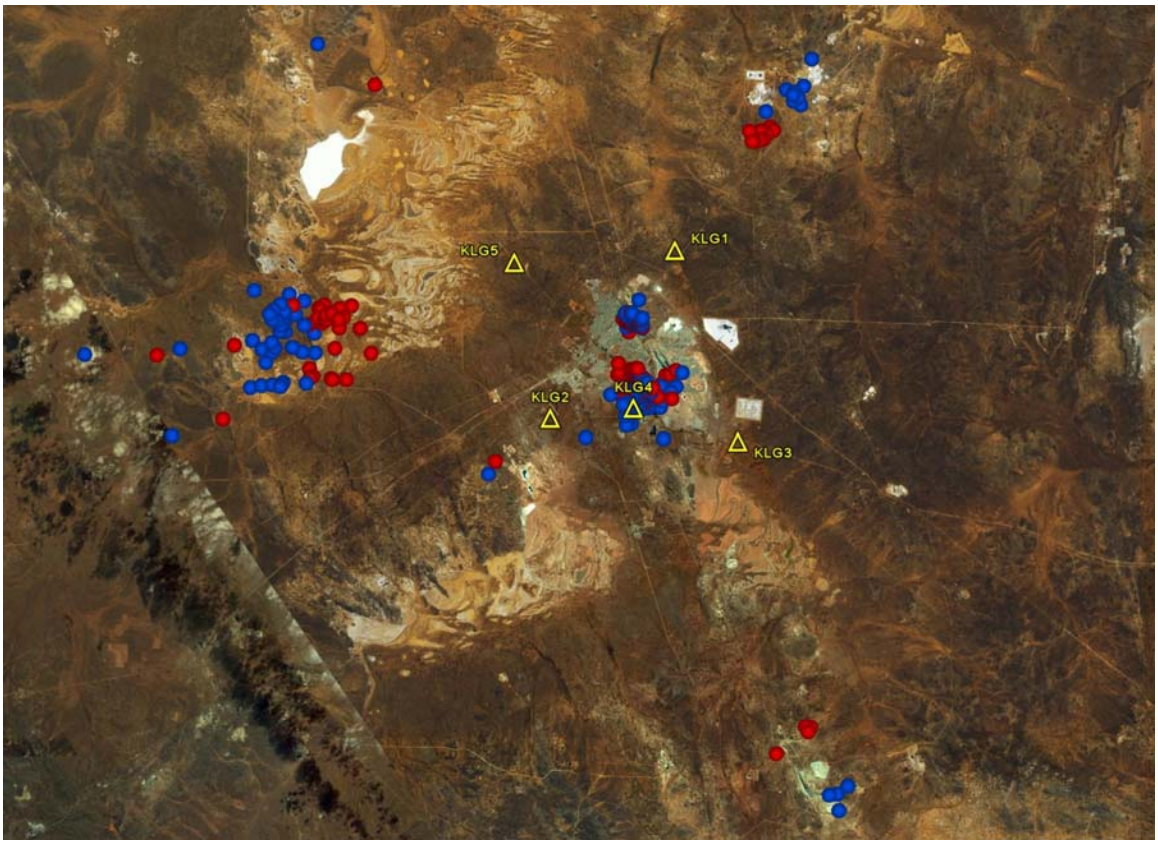

Figure 5. Sensitivity of epicentral locations to velocity models. Blue circles = WA2A model; Red circles = IASPEI91 model; Triangles = temporary seismic stations