A 3 km deep on-fault thermometer array for measuring the heat generated by forthcoming earthquakes in a South African gold mine.

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Design of frictional heating measurement.

At Mponeng gold mine, South Africa, thin-tabular gold reef development at a depth of 3 km intersects with a major geological fault called Pretorius Fault (hundreds meters total offset). Some mining tunnels has already got through this fault, exposing the local fault structures on the tunnel wall [Kato et al., 2001 Joint Meeting]. From one of these intersections, we drilled seven boreholes (Fig. 1) to build a thermometer network to quantify frictional heating by forthcoming earthquakes (M2-3) [Ogasawara et al. 2003, IUGG, Zisin Journal, Chikyu Monthly; 2004 this meeting]. Because we need to observe a temperature change that is quick enough to be distinguished from various background changes, sensors must be very close to the slipping plane. Difficulty increases with the cube of the sensor-fault distance d; the magnitude of the temperature rise decreases with 1/d, the time to peak increases with d^2.

At d=100 cm, a value used for initial design, temperature peak occurs 10 days after the earthquake. Assuming 1 mC/day heating from cement being the most serious noise, we estimate the resolution limit is a temperature rise of 10mC/10days, a change expected from a 2 cm slip at a 20 MPa friction, some one tenth of the value expected for a M3 event at the dynamic friction known from laboratory tests. Stability and resolution of our quartz temperature sensors [Yamauchi and Miyajima, 1996, Zisin] is good enough to detect this change. As detailed below, 3-D fault structure revealed by our drilling suggests that we will achieve d=100cm, probably some sensors located even closer to the future slip plane.

Borehole layout and fault structure at a 10 cm scale.

Although Pretorius Fault is a thick (20 m) zone of complex shear structures, we have identified a single weak plane (grey dotted line), with continuity confirmed at least over a 15m (lateral) x 7m (vertical) extent of its intersections with our fanned-out boreholes. Following are the supporting observations of the cores, the tunnel wall, and the borehole camera records.

1. A narrow (2-20 cm) severe damage on the borehole wall was recognized in all of the 5 holes going through this plane. At these damages, rock material was lost from the borehole wall.
2. These damages were found restrictively on a fairly flat plane extending from a 20 cm-thick shear zone exhumed on the tunnel wall (labeled M).
3. Core material recovered from this plane, as well as the plane M exhumed on the tunnel, is weak (friable).
4. This weak plane bounds the southern end of the complex fault zone; A single lithology of basaltic lava occurred to the south, while lithology to the north of this boundary is a typical complex fault zone, which consists of 2-300 cm thick layers of quartzite, cataclasite, and lava, appearing in variable sequences.

Since Pretorius fault is not currently active and most old detritus material are now lithified well, it was of some surprise to us, that the fault has such a distinct weak plane. This finding is encouraging in designing experiments that requires installing sensors very close to the fault beforehand. For the holes going through the boundary plane, we can install sensors with a spatial accuracy of 5 cm relative to the fault. Even the stop holes, which are advantageous in minimizing disturbances on the fault, can be located relative to this weak plane fairly accurately (about 20 cm), thanks to the simple geometry of the plane constrained by the surrounding through holes.

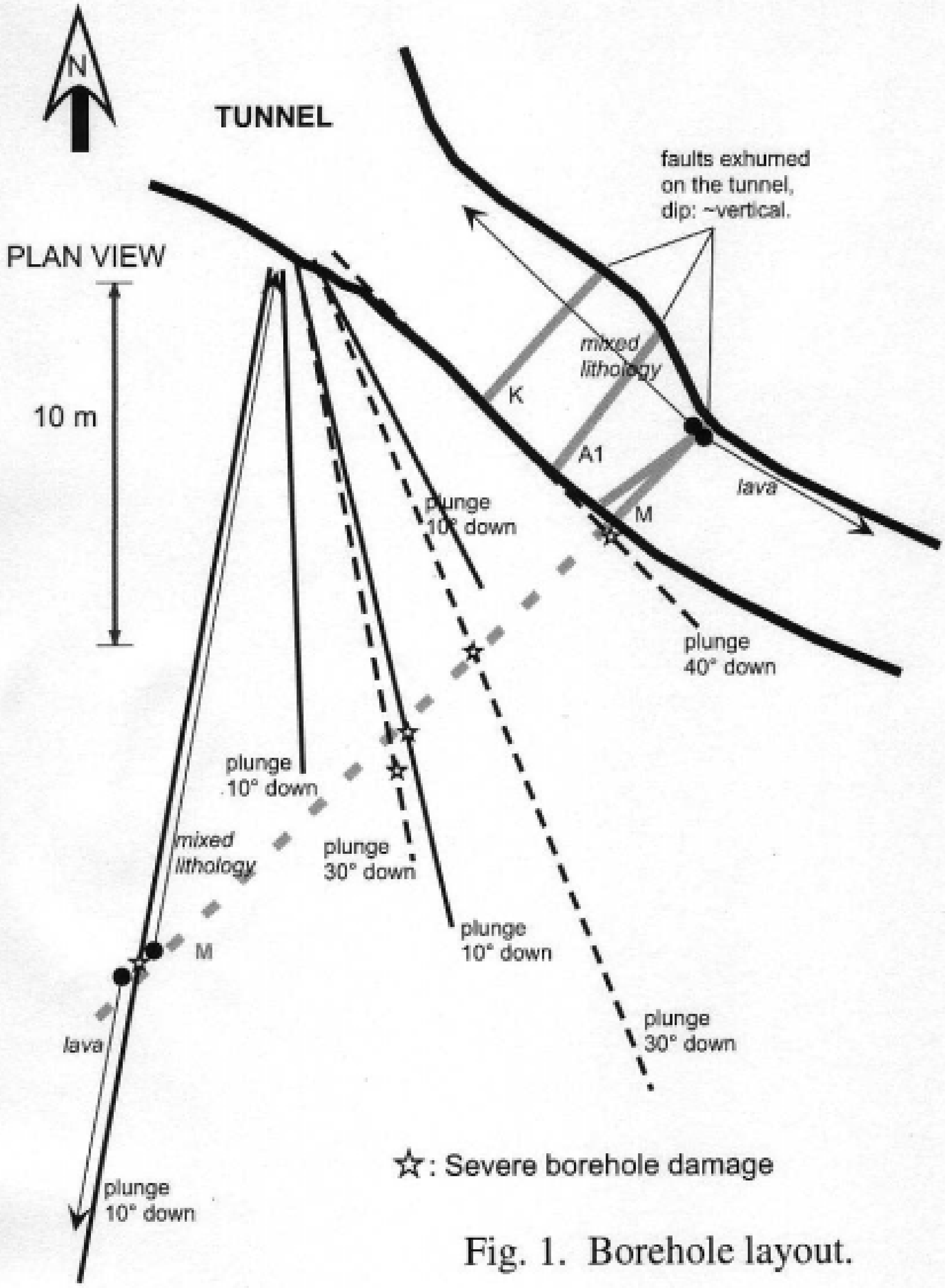

Fig. 1. Borehole layout.