JOINT CHANNELS IN RESERVOIR ROCKS OF THE NGAWHA GEOTHERMAL FIELD, NORTHLAND, NEW ZEALAND

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ABSTRACT

Hot water ascends and moves laterally through the greywacke and argillite rocks, which comprise the reservoir of the Ngawha Geothermal Field, by way of closely spaced (about 15 per metre), narrow (0.5 to 1.0mm but occasionally up to 3cm wide), continuous and discontinuous joints which are oriented in at least three directions:

	strike	dip
Commonest	010°	70-80°E
Second Commonest	130°	90°
Third Commonest	070°	80° S

INTRODUCTION

Rocks of the Ngawha geothermal field consist of about a 500m thick sequence of greatly disturbed but impermeable sediments overlying dense, non-porous greywackes and argillites of Mesozoic Age. Young faults occur in the Ngawha area and their locations have been mainly recognised through the study of aerial and Landsat photographs (G.W. Grindley and D.N.B. Skinner, written communication); some wells have been sited to intersect these faults since they are believed to serve as channels for the ascending thermal fluids. The purpose of this paper, however, is to draw attention to other permeable features in the reservoir greywackes and argillites - the great number of joints they contain.

EVIDENCE OF JOINTING FROM THE CORES

Discontinuous cores of greywacke and argillite show numerous joint surfaces, in places filled, or partly filled, with quartz or calcite. Unfortunately the cores are not oriented, making it impossible to determine the attitudes of these joints and veins except to note that most dip steeply and that they occur in at least two sets of directions; nor can the dimensions of these features be measured or deduced. However, the occasional presence in cuttings of euhedral hydrothermal quartz crystals that have grown into cavities indicates channels, either joints or faults, can be at least 5mm wide; elsewhere platey calcite about lcm long and 2mm thick shows fluid channels must have been locally at least 2mm wide.

EVIDENCE FROM EXPOSURES OUTSIDE THE NGAWHA GEOTHERMAL FIELD

Rocks which are of the same lithology as those that comprise the cores are well exposed at Puketona Quarry (N15/492476) and on the right bank of the Waipapa River (N10/193501), i.e. 16.5km north-east and 20.6km north-west respectively of the Ngawha Springs (Figure 1).

Because these two areas are approximately equidistant northeast and northwest of Ngawha Springs, it is probable that examination of permeable features in rocks at both locations would aid in understanding fluid flow in the reservoir rocks of the Ngawha Field. At both the Puketona Quarry and Waipapa River outcrops, joints clearly constitute the main permeable features in the greywacke and argillite rocks.

Number of Joints

Joints are very common at both locations (Table 1) and indeed elsewhere in the greywackes and argillites exposed north of Moerewa. Thus the joint density in the greywacke and argillites at both locations is similar and their mean density is 15.4 ± 4.1 per metre.

Shape of Joints

Most joints are straight over the outcrops but, rarely, some (11 in 311, i.e. 3.5%) have gently wavey strikes or even more rarely (1 in 311) are distinctly arcuate. Some of the major joints at the Puketona Quarry can be traced for up to 30 metres and were certainly longer before quarry excavations began. However, many joints are discontinuous both at Puketona Quarry (85 in 163, i.e 52%) and along the Waipapa River bank (128 in 144, i.e. 89%) in that they cannot be traced over the total extent of their outcrops.

Most joints are between about 0.1 and 2.0mm wide but occasionally may be up to 2cm wide; however, they have no doubt widened slightly as a result of unroofing. On the other hand, joints in rocks of the Ngawha reservoir have probably also widened where there occur high local fluid pressures.

Joints at neither outcrop contain secondary minerals and this contrasts with both the obviously older veins in the same rocks and veins in the cores and cuttings from the Ngawha drillholes and with quartz and calcite that has deposited into joints at Ngawha in response to the current geothermal activity.

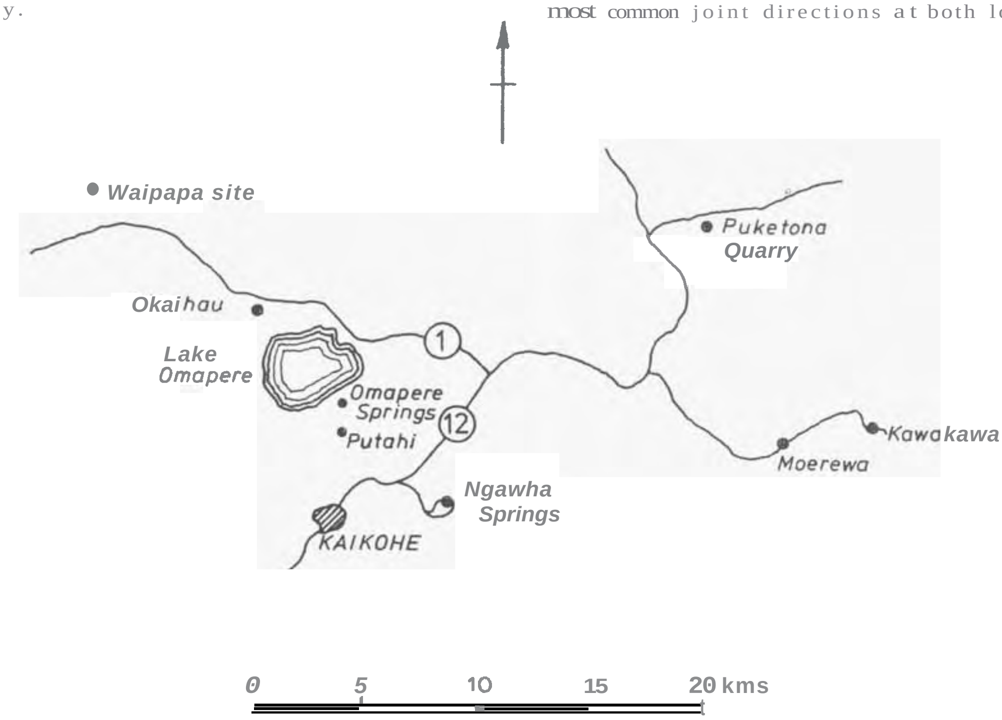

FIGURE 1 : LOCATION OF GREYWACKE EXPOSURES WHERE JOINTS WERE EXAMINED.

TABLE 1: DENSITY OF A TOTAL OF 264 JOINTS AT PUKETONA QUARRY AND ON THE RIGHT BANK OF THE WAIPAPA RIVER.

Location	Bearing of vertical Rock Surface (°)	Width of Face (m)	Number of 'significant' joints	Joint Density m^{-1}
Puketona Quarry	270	3.7	56	15.1
	270	2.8	25	9.0
	160	3.0	54	18.0
Waipapa River right bank	210	3.5	69	20.0
	272	4.0	60	15.0

Orientation of Joints

Figure 2 shows the orientations of 311 joints measured at Puketona Quarry and on the right bank of the Waipapa River; results are also summarised in Table 2.

Inspection of Figure 2 and Table 2 suggest that the most common joint directions at both locations nearly coincides (mean dips 70E, 80E°; mean strikes 018, 004°). The second most common orientation in both areas is also the same (mean dips 88E, 90; mean strikes 131, 132°) and there is a further set of joints at the Puketona Quarry (82S dip; 078°

TABLE 2: SUMMARY OF JOINT ORIENTATIONS AT THE PUKETONE QUARRY AND ON THE RIGHT BANK OF THE WAIPAPA RIVER.

Location	Puketona Quarry		Waipapa River		
Frequency	Strike (°)	Dip (°)	Freq.	Strike (°)	Dip (°)
>15	015–022	65-75E	>15	359–007	72-88E
12–15	130–132	84E–88W	5–10	128–136	83E–83W
10–12	074–082	78-86S	5–10	072–085	58-86S
10–12	053–055	49–53s			

strike) which has a similar orientation (dip 82S, strike 078°) to a minor set of joints at the Waipapa River outcrop. On the other hand, an additional minor joint orientation at the Puketona Quarry (dip 50S; strike 054°) is not represented at the Waipapa River outcrops.

Because the attitudes of three sets of the joints in the greywackes and argillite are similar both north-east and north-west of Ngawha, it is highly probable that the same rocks also have joints with similar orientations within the geothermal reservoir itself; i.e. most probably strike slightly east of north and dip to the east at about 75°; the second commonest set of joints are vertical and strike south-east; a third, and minor, set strike at about 70° and dip south at close to 80°.

that underlie the nearby impermeable Cretaceous-Tertiary cover. At first sight, these models appear to be inconsistent with the conclusions that all faults and joints within the field dip steeply. However, reconciliation is possible if it is recognised that the joints are very numerous and have at least three orientations; thus the greywackes and argillites are effectively broken up into a multitude of closely spaced, irregular blocks between which lateral fluid flow is possible. I, therefore, suggest that at Ngawha, fluids move laterally within the reservoir rocks along a multitude of small scale, 3-dimensional zig-zag shaped paths.

Where fluids ascend from depth beneath the zones of lateral flow they probably do so along steeply dipping faults or joints. If they move via

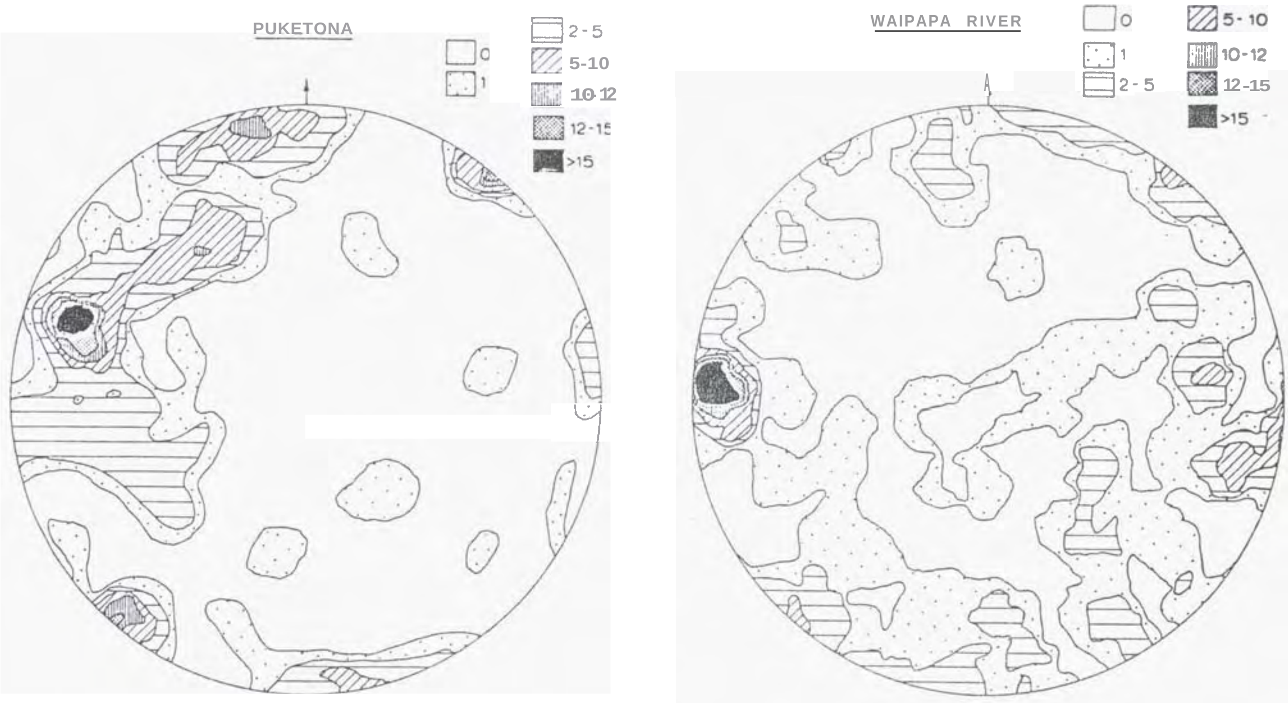

FIGURE 2 : LOWER HEMISPHERE EQUAL AREA PLOTS OF THE POLES OF JOINTS, WHOSE ORIENTATIONS WERE MEASURED ON GREYWACKE AND ARGILLITE ROCKS, EXPOSED AT PUKETONA QUARRY AND ON THE RIGHT BANK OF THE WAIPAPA RIVER; n = 264.

PERMEABILITY AT NGAWHA

Because joints have been shown to be very abundant in the greywackes and argillites that comprise the Ngawha reservoir, it is probable that they also serve as major channels for conducting the thermal fluids of the field, despite their narrowness.

Models of fluid transport in the Ngawha Field indicate that considerable lateral flow occurs at shallow levels within the greywackes and argillites

joints then the deduced orientations of the joints means that the fluids ascend from a deep source located in a direction south-east or east from the surface features of the field. There is little doubt that where they occur faults are permeable, as they are commonly wider and more continuous than joints although they are far fewer; however, one important consequence of faulting may have been to generate some of the very numerous joints. Kear and Hay (1961) show that a major NNW striking fault occurs in the Waipapa Valley and a 7-18cm thick vertically dipping fault breccia indicates that at least one east-west fault occurs in rocks exposed at the Puketona Quarry. However, the relationship between joints and faults in the greywackes and argillites of Northland is at present poorly understood; one would expect joints to be more numerous closer to faults but this has not yet been demonstrated.

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