STRUCTURAL CONTROLS ON THE OCCURRENCE OF ACID ZONE§ IN THE LAGUNA0 AND BALAS-BALAS SECTORS OF THE PALINPINON GEOTHERMAL FJELD, NEGRO§ ORIENTAL, PHILIPPINES.

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Abstract

Shallow to deep acid zones characterized by the presence of alunite, kaolinite, dickite, pyrophyllite and diaspore were encountered by the wells drilled in the Lagunao and Balas-balas sectors of the Palinpinon Geothermal Field. Some of these zones are related to the faults that were intersected by the wells. Some of these acid zones are cased-off and isolated from the open-hole section of the well, preventing the acid fluids to enter the well and cause acid discharge. Some of these zones, however, were intersected at the open sections of the well and cause acid discharge. The present strategy in developing these sectors is to intersect the identified acid faults at much deeper elevations where the geothermal fluid is of neutral pH

1.0 Introduction

Acid alteration assemblages characterized by the presence of alunite, diaspore, kaolinite, dickite, and pyrophyllite were encountered by a number of wells drilled in the Palinpinon Geothermal Field located in the southern part of Negros Island. These Alteration minerals were deposited either in the matrix of the volcanic breccia layers or along the fracture zones related to the numerous faults that transect the area. Pernieability in the field is mostly controlled by these fault structures (Urbino et al., 1988) such that geothermal well dnlling targets these faults. The association of the acid alteration minerals with some of these faults caused concerns that acid fluids may be channeled by these faults, thereby producing acid discharges from the wells or damaging the well casings (Geoscientific Dept, 1988). PNOC's experience in operating the Palinpinon Field for the past 15 years has borne out these concerns.

The acid minerals were postulated to have been deposited by percolating acid fluids produced by the near-surface oxidation of H_2S by oxygenated meteoric waters (Geoscientific Dept, 1988) or by magmatic contribution (Bayon, 1996). The mechanism for the formation of acid fluids will not be discussed in this paper.

This paper aims to establish the vertical and lateral distribution of the acid alteration minerals associated with the five structures mentioned above. This will aid in defining the levels at which these faults may be intersected without causing adverse effects to the well discharges.

2.0 Background

The Palinpinon Geothermal Field is located on the northern slope of the dormant andesitic Cuernos de Negros Volcano (Fig.1). The area is underlain by a suite of volcanic, sedimentary, and intrusive rocks ranging in age from Miocene to Recent. These rocks were intruded by dikes related to the latest volcanism event (Aniceto-Villarosa et al., 1988).

The field is also transected by numerous faults (Fig.2). Some of these faults trend to the northwest and to the north in the Nasuji-Sogongon and Balas-balas sectors at the western and central portions of the field, respectively. Northeast- and north-trending faults, on the other hand, transect the Puhagan, Ticala, and Malaunay sectors to the northeast.

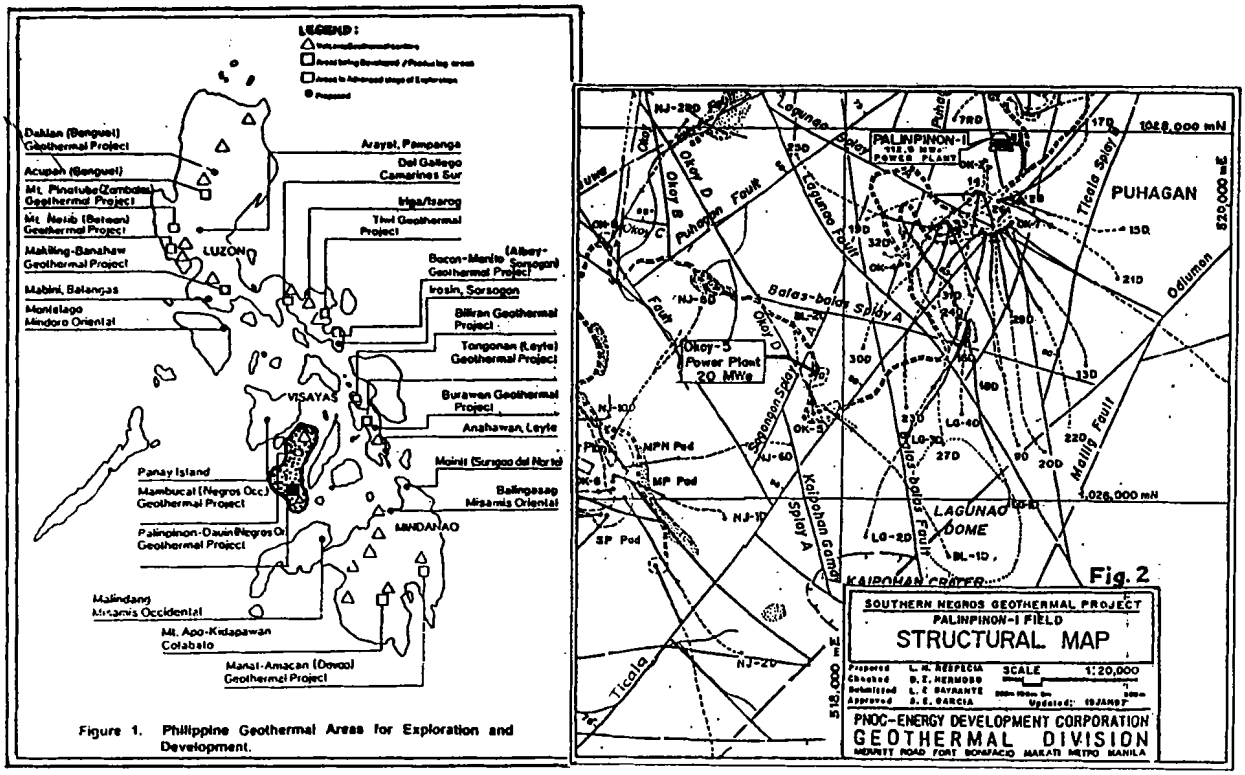

Figure 1. Philippine Geothermal Areas for Exploration and Development.

Amistoso et al. (1993 and Urbino et al. (1988) postulated that the upflow for the system lies to the south of Puhagan and southeast of Nasuji-Sogongon. with the main outflow to the northeast towards the Okoy Valley and a minor northwest outflow towards Nasuji-Sogongon. The outflow directions are controlled by the faults that transect the area. Temperatures of as high as 329°C was encountered in well PN-20D (Seastres, 1993).

The Lagunao and Balas-balas Sectors of the field is nearest the postulated upflow of the geothermal system. near the vicinity of the Lagunao Dome. Cold acid altered grounds known locally as "kaipohan" are also found along these sectors. To date, five *(5)* wells were drilled towards these sectors to augment the steam supply to the Palinpinon-1 Power Plant at Puhagan and the OK-5 Modular Power Plant at Balas-balas (OK5, BL1D. LG1D. LG2D, LG3D. and LG4D. Five *(5)* faults are also transecting these sectors, namely the Lagunao. Odlumon. Ticala, Balas-balas. and Balas-balas Splay A. These faults were intersected by the Lagunao and Balas-balas wells and also by some of the wells drilled in the Puhagan and Nasuji drill pads.

This paper will compare the vertical and lateral distribution of the acid alteration minerals in relation to the five faults mentioned above. using data from the five wells in these sectors and also from adjacent wells. The downhole fault correlations were taken from Camit and Villarosa (1996) who established a preliminary structural correlation of the faults that were intersected by the wells.

3.0 Results and Discussions

3.1 Lagunao Fault

The Lagunao Fault is one of the major fault structures that transect the area. It trends NW-SE an dips steeply to the NE. Table I shows the wells that intersect this fault along its southeastern segment. Fig. 3 shows the fault profile and wells. Most of the wells' intersection with the Lagunao Fault were along the open hole section, except in LG2D and LG3D. Acid alteration minerals were associated with tlus fault in LG1D and LG2D. Acid discharge was experienced in LG1D since the fault was along the open hole. LG2D, on the other hand, discharge neutral fluids since the fault intersection has been cased-off in this well (D. Z. Hermoso,

pets. comm.). This *structural* correlation *suggest* that the Lagunao Fault may have neutral fluids at elevations deeper than -42 mSL. No data is available at elevations between -42 mSL and -773 mSL.

	NW End									SE End
Well	PN30D	PN24D	PN23D	PN16D	PN27D	LG2D	LG3D	LG4D	LGID	OK9D
Fault Elev. (mSL)	-730 to -1040	-1903 to -2140	-753 to -951	-2045 to -2236	-933 to -1243	147 to 35	39 to -42	-566 to -773	57 to -13'	-1421 to -1600
PCS Elev. (mSL)	-529	-666	-489	-942	-425	-286	-242	-170	-279	-602
Charac-teristic	Neutral (?)	Neutral	Neutral	No data	No data	Acid	Neutral (?)	Neutral (?)	Acid	Neutral
Remarks (depths in mSL)	No acid mins in Core 1	No acid mins in rock cuttings	No acid mins m rock cuttings	Blmd drill; no core.	Blmd drill; no core.	Dsp, Pyp, Di m rock cuttings.	No acid mins m cuttings.	Blind drill, no core.	Dsp, Pyp m rock cuttings.	No acid mins m Core6

3.2 Odlumon Fault

Odlumon Fault is another of the major structures that transect the sector, trending to the northeast and dipping to the northwest. Fig. 4 shows the fault profile while Table II lists the elevations at which the various wells intersect this structure, from its southwest end (as at OK11D), and also near its northeast end (as at PN15D). All of the wells' intersection with this fault occur along the wells' open-hole section. Six (6) of the wells listed below (OK10D, PN13D, PN22D, PN20D, LG1D, and BL1D) discharge acid fluids (D. Z. Hermoso, pers. comm.). Except for BL1D and PN13D, the four wells have acid alteration minerals associated with their intersections with the Odlumon Fault. The acidity in BL1D may or may not be related to the Odlumon Fault but to the Balas-balas fault (see section 3.4, this paper). Likewise, the acidic discharge in PN13D may also not be related to the Odlumon Fault but to the Ticala Splay B structure, which will not be discussed in this paper. Further studies may also be conducted regarding this subject.

The data for the Odlumon Fault's well intersections suggest that neutral fluids may be intersected at elevations deeper than -1224 mSL near the vicinity of PN20D or at elevations deeper than -933 mSL near the bottom of LG2D.

TableII. Odlumon Fault Well Intersections. Elevations are in meters relative to sea level (mSL).

	SW END													NE END
Well	OK 11D	NJ 2D	LG 2D	BL 1D	PN 27D	LG ID	OK 9D	PN 20D	PN 18D	PN 22D	PN 13D	OK 10D	PN 21D	PN 15D
Fault Elev. (mSL)	-629	-1398 to -1658	-933 to -1183	-685 to –732	-1958 to -2049	-183 to -303	-1154 to -1421	-974 to -1224	-1960 to -2399	-664 to -794	-1153 to -1339	-614 to -768	-1475 to -1672	-1895 to -2001
PCS Elev. (mSL)	-217	-773	-287	-107	425	-280	-601	-441	-599	-644	-641	488	-467	429
Charac-teristic	neut. (?)	neut.	no data	neut?	neut.	acid	neut. (?)	acid	neut.	acid	neut.	acid	neut	neut (?)
Remarks (depths in mSL)	No acid in core1 & core 2	no acid in core 1	Blind drill, no core.	down hole pH= 4.5	no acid in core 1	acid min in cut-tings	acid min in cut-tings		acid min in cores 1 to 3	min in tings	acid in core 1 to2	min in core 1	core	blind drill, no core

3.3 Balas-balas Splay A

The Balas-balas Splay A fault trend west-northwest and is postulated to be dipping to the southwest. Fig. 5 shows the fault profile. As seen in Table III, this fault has been cased off in LG1D, LG2D, and LG3D, while the remaining wells have this fault along their open hole sections. Except in PN20D, the alteration minerals associated with the well intersections are assumed to have been deposited by near-neutral pH fluids, as

supported by the neutral pH fluids discharged from these wells. PN20D, on the other hand, discharged acid fluids.

It may be noted that the intersection of PN20D with the Balas-balas Splay A and Odlumon faults Seem to overlap. This may suggest that the acidity in PN20D may not be due to its intersection with the Balas-balas Splay A but to the Odlumon Fault since the adjacent well OK9D have neutral pH mineral assemblage at almost the same elevations. If such is the case, this may suggests that neutral fluids may be encountered upon intersecting the Balas-balas Splay A at any elevation. Further studies may conducted to check these assumptions.

Table.III. Balas-balas Splay A Fault Intersections. Elevations are in meters relative to sea level (mSL)

	NW END											SE END
Well	BL2D	PN 30D	PN 23D	PN 27D	LG 2D	LG 3D	LG 4D	LG 1D	PN 18D	OK 9D	PN 20D	PN 22D
Fault Elev. (mSL)	-634	-1425 to -2158	-1255 to -1823	-1033 to -1400	217 to 147	136 to 47	-566 to -773	347 to 287	-1960 to -2234	-982 to- 1154	-948 to -1121	-1394 to -1574
PCS Elev. (mSL)	-107	-529	-489	-425	-285	-242	-170	-280	-599	-602	-441	-644
Charac-teristic	neutral	neutral (?)	neutral	neutral (?)	neutral	neutral	neutral (?)	neutral	neutral	neutral	acid	neutral
Remarks (depths in mSL)	no acid in cut-tings	blind drill; no core	no acid in core 1 and 2	blind drill; no core	no acid in rk cut-tings	no acid in rk cut-tings	blind drill; no core	no acid in cut-tings	no acid in core 1	no acid in core 3 and 4		no acid in core 1.

3.4 Balas-balas Fault

Five wells intersected this north-northwest trending fault at the vicinity of the Lagunao and Balas-balas sectors, as seen in Table IV and Fig. 6. This fault has been postulated to be dipping steeply to the southwest. All the five wells intersected this fault along their open hole sections. LG2D and BL1D have associated acid alteration minerals along their intersections with this fault. However, only BL1D discharged acid fluid while LG2D discharged neutral pH fluid

The intersection of BL1D with the fault is much deeper than that in LG3D. The acid aheration was also associated with BL1D's fault intersection. BL1D was drilled towards the Lagunao Dome, similar to LG1D. Both these wells discharged acid fluids. The presence of deep acidity in BL1D along the Balas-balas Fault may be related to its having been drilled towards the Lagunao Dome, making it one of the two wells drilled nearest the upflow of the geothermal system. Drilling at elevations deeper than -1000 towards the Lagunao dome may encounter deep-seated acidity in this sector. Outside the Lagunao Dome, however, wells may be drilled deeper than -600 mSL to -1000 mSL to avoid encountering acid fluids. Additional investigation may be necessary to confirm this hypothesis.

Table IV. Balas-balas Fault Intersections. Elevations are in meters relative to sea level (mSL).

					SE END
Well	PN30D	PN23D	LG2D	LG3D	BL1D
Fault Elev. (mSL)	-1041 to -1326	-1457 to -1823	-375 to -634	-570 to -729	-1028 to -1148
PCS Elev. (mSL)	-529	-489	-287	-242	-107
Characteristic	neutral	neutral (?)	acid	neutral	acid
Remarks (depths in MSS)	no acid in rock cuttings and core 1	no acid in core 1 and core 2	acid minerals in cuttings	no acid minerals in rock cuttings.	blind drill; no core; downhill pH=3

3.5 Ticala Fault

Table V and Fig. 7 shows the intersection of the Ticala Fault with the wells drilled in the the vicinity of the Lagunao and Balas-balas sectors. Of these eight (8) well, three have their Ticala fault intersections cased off, namely OK5, BL1D, and PN16D. only BL1D have acid mineral assemblage associated with its fault intersection, but along the cased-off section. The acid discharge of BL1D may be from its intersection with the Balas-balas Fault.

To avoid encountering acidic minerals or fluids, the Ticala Fault should be intersected at elevations deeper than 311 mSL, as indicated in BL1D.

Well Intersections. Elevations are in meters relative to sea level (mSL).

	SW END						NE END	
Well	**NJ2D**	**OK5**	**BL1D**	**PN20D**	**PN23D**	**PN24D**	**PN16D**	**PN31D**
Fault Elev. (mSL)	-784 to -1099	470 to 32	542 to	-1423 to -2098	-531 to -666	-1903 to -2141	306 to -26	-852 to -1619
PCS Elev. (mSL)	-773	-1037			-489	-666	-942	-276
Characteristic	neutral	neutral	acid	neutral (?)	neutral	neutral	neutral	neutral
Remarks (depths in mSL)	no acid min. in cuttings	no acid min. in cuttings	acid min. in cuttings	blind drill, no core	no acid min. in cuttings	no acid min. in cuttings	no acid min. in cuttings	no acid in core 4

4.0 Summary and Conclusions

The acid alteration mineral assemblages and acid fluids associated with the Lagunao, Odlumon, Balas-balas Splay A, Balas-balas, and Ticala faults may be limited along specific elevations. Intersecting these faults at elevations deeper than the acidic zones may increase the probability that neutral pH fluids may be encountered. Based on the available data, the Lagunao Fault should be intersected at elevations deeper than -42 mSL to avoid acid fluids. The Odlumon Fault may be intersected at elevations deeper than -1224 mSL near the vicinity of PN20D. Near LG2D, however, the Odlumon Fault may be intersected at elevations deeper than -900 m. No acid alteration assemblage appears to be directly related to the Balas-balas Splay A fault at any elevation. For the north-northwest trending Balas-balas Fault, it may be intersected between elevations of -600 mSL and -1000 mSL inside the Lagunao Dome. Outside the dome. however. the fluids along the fault may be of neutral pH at elevations deeper than -1000 mSL. Neutral alteration and possibly neutral pH fluid may be encountered when the Ticala Fault is intersected at elevations deeper than 311 mSL.

The present strategy in drilling wells in the Lagunao and Balas-balas sectors is to intersect the identified acid faults either at depths where they can be sufficiently cased-off or intersect them at depths where the acid fluid and resulting alteration assemblage has already been neutralized.

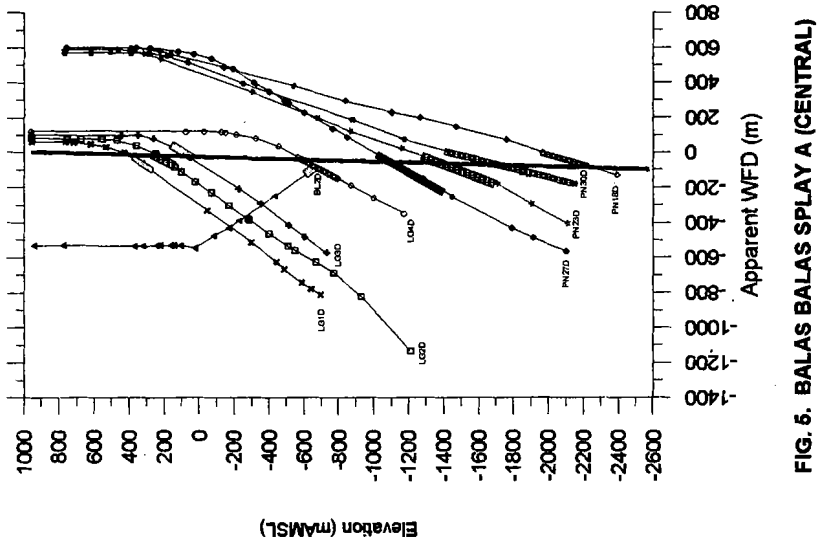

FIG. 5. BALAS BALAS SPLAY A (CENTRAL)

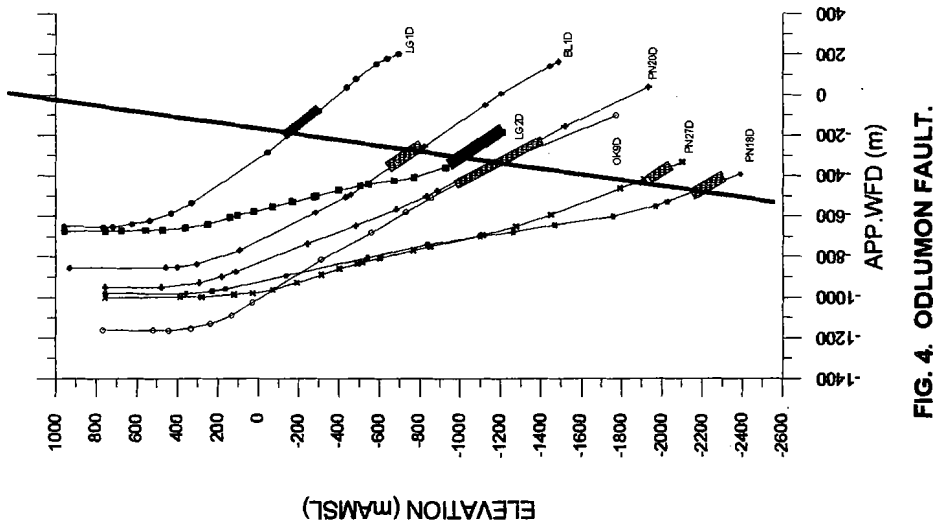

FIG. 4. ODLUMON FAULT.

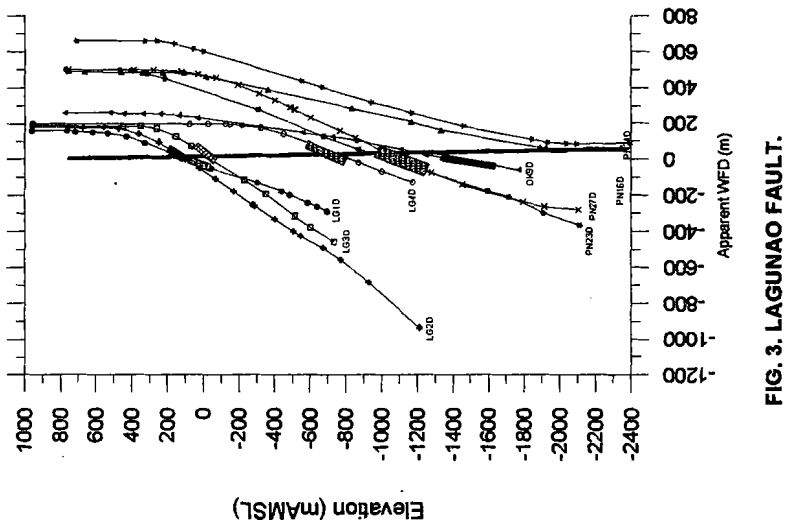

FIG. 3. LAGUNAO FAULT.

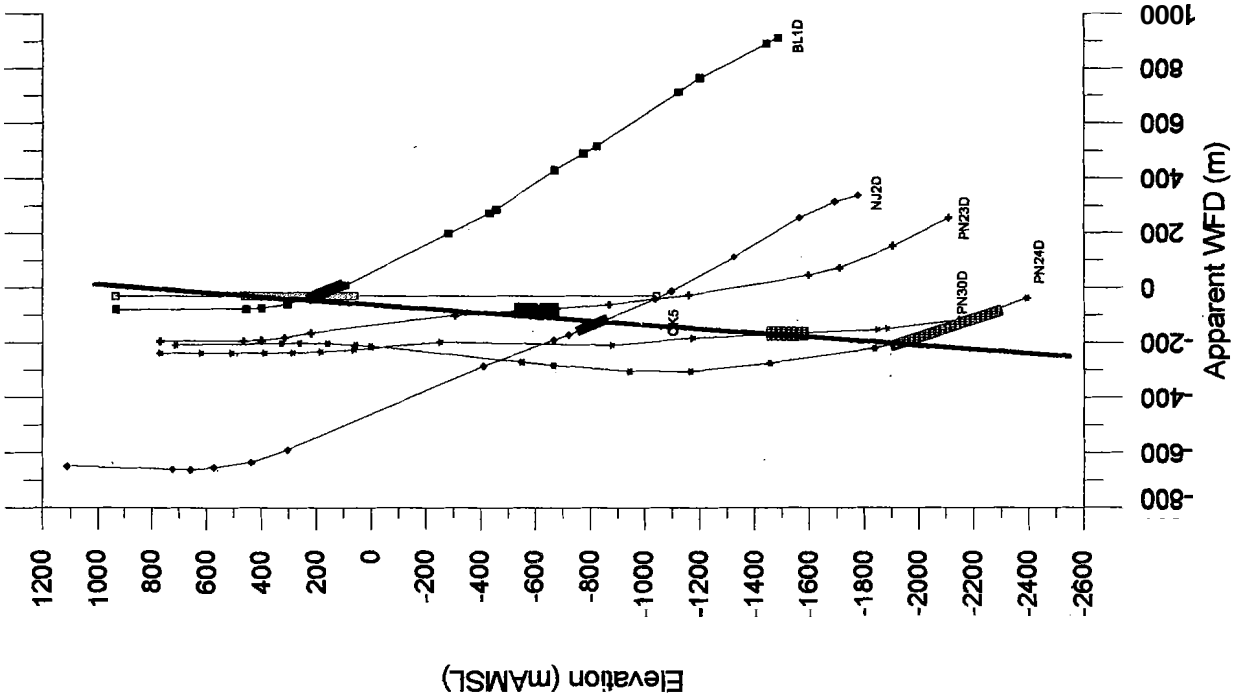

FIG. 7. TICALA FAULT (CENTRAL)

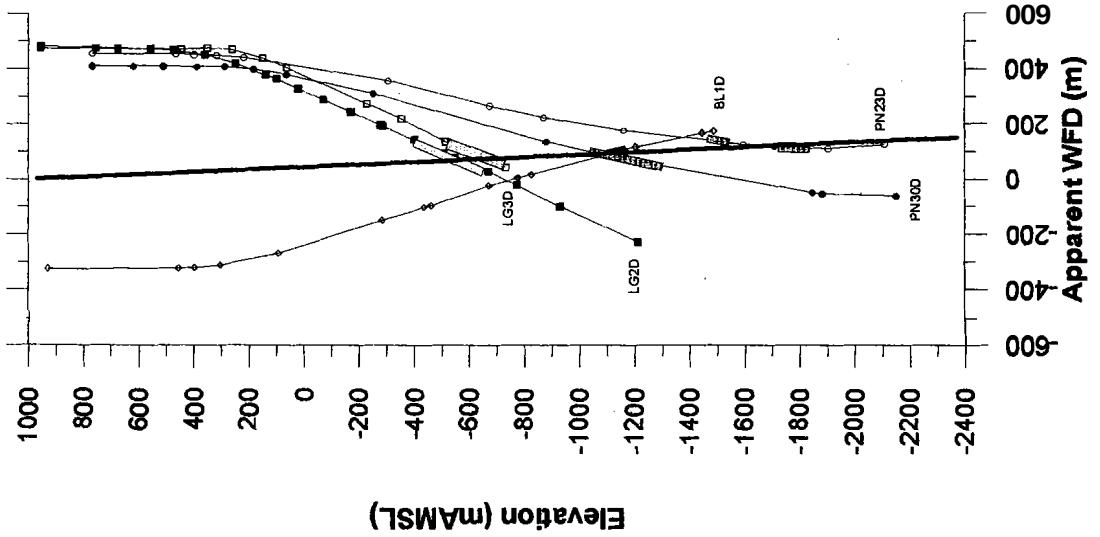

FIG. 6. BALAS BALAS FAULT

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