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LAMPIRAN

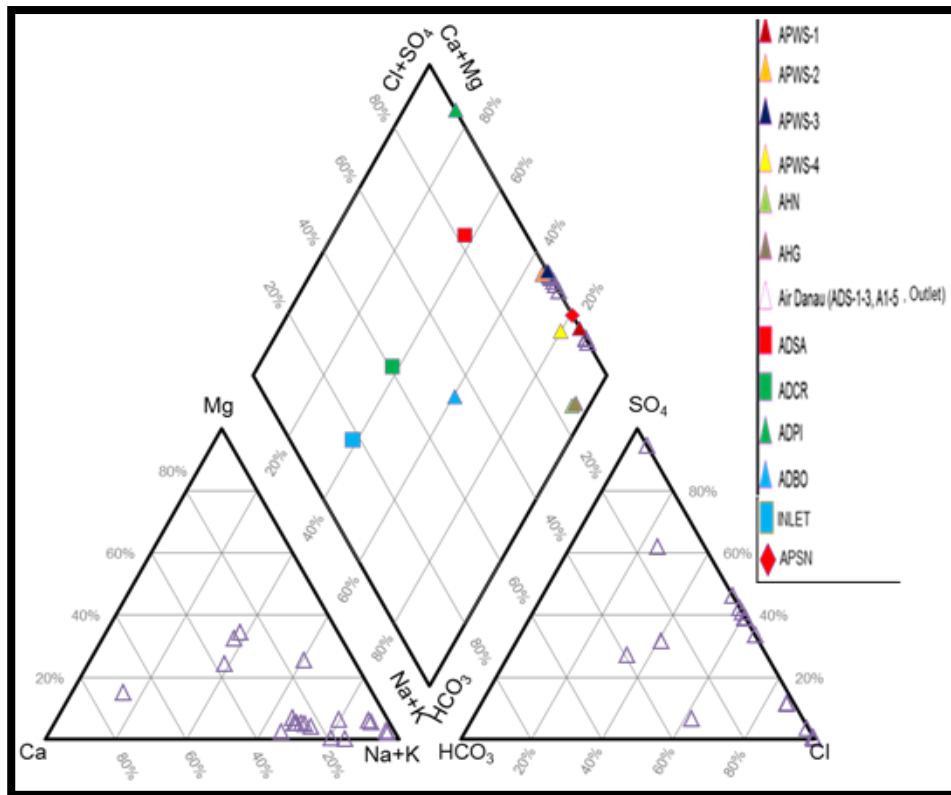
Lampiran 1 Tabel hasil analisis unsur air panas bumi daerah penelitian (modifikasi PSDG, 2015)

Sample Lable	APWS-1	APWS-2	APWS-3	APWS-4	AHN	AHG	ADS-1	ADS-2	ADS-3	ADSA	ADCR	ADPI	ADBO
T (°C) Air	81.57	71.13	36.8	53.9	36	36	30.27	29.16	28.9	25.34	23.54	25.1	33.43
T (°C) Udara	24.91	24.91	24.3	25	32.03	29.6	24.91	25.99	26.2	28.07	23.7	25.05	28.32
pH	5.79	6.21	3.67	5.98	6.75	7.07	2.52	2.54	2.52	7.65	7.88	4.51	5.73
Densitas (kg/L)	0.9708	0.9771	0.9934	0.9862	0.9936	0.9936	0.9955	0.9959	0.9959	0.9969	0.9974	0.9970	0.9945
EC (µS/cm)	53200.00	36000.00	627.00	11200.00	16950.00	17990.00	3930.00	2720.00	2500.00	60.00	52,1	108.00	1000
Li (mg/kg)	19.448	10.480	0.131	2.626	1.781	1.570	0.552	0.472	0.783	0.010	0.010	0.010	0.070
Na (mg/kg)	12540.270	4473.123	45.210	2024.948	4152.370	4385.853	251.324	190.298	197.453	3.641	2.888	3.430	76.911
K (mg/kg)	1159.854	475.386	8.386	100.730	136.940	131.998	20.914	14.570	14.469	0.000	0.080	0.000	6.898
Ca (mg/kg)	2050.340	2025.637	17.446	314.014	84.205	88.522	13.038	10.885	11.045	2.568	1.845	14.464	16.500
Mg (mg/kg)	24.063	96.285	2.809	88.248	66.080	52.413	8.448	7.411	7.470	1.675	1.404	1.886	17.958
SiO2 (mg/kg)	56.376	127.326	48.039	101.085	57.354	67.318	43.012	43.008	42.613	10.713	10.718	7.884	85.860
B (mg/kg)	592.247	451.847	1.470	252.586	269.139	279.072	28.990	20.294	24.680	0.110	0.110	0.110	2.785
Cl (mg/kg)	23295.343	11861.843	90.148	3666.809	5080.163	5314.853	560.577	414.517	414.485	3.210	1.945	2.056	59.325
F (mg/kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.110	0.000	0.000	0.040	0.030	0.070	0.000
SO4 (mg/kg)	202.926	47.078	104.825	202.393	1067.479	1140.845	383.586	387.906	412.296	13.341	5.214	49.409	116.116
HCO3 (mg/kg)	76.978	424.347	0.000	417.847	1752.127	1631.360	0.000	0.000	0.000	4.795	14.448	0.000	216.184
CO3 (mg/kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NH4 (mg/kg)	36.053	10.644	0.503	9.126	4.931	6.944	1.909	1.607	1.205	0.201	1.003	0.301	3.218
As (mg/kg)	1.854	0.205	0.000	0.507	0.201	0.503	0.000	0.000	0.000	0.000	0.000	0.000	0.000
meq. kation	684.254	317.837	3.541	114.475	194.297	203.500	15.994	12.821	13.300	0.437	0.392	1.075	6.013
meq. anion	662.648	342.558	4.726	114.503	194.254	200.422	23.806	19.770	20.277	0.449	0.402	1.090	7.634
% IB	1.604%	-3.743%	-14.323%	-0.012%	0.011%	0.762%	-19.628%	-21.320%	-20.777%	-1.365%	-1.206%	-0.718%	-11.880%

Tabel hasil analisis unsur air danau SN (modifikasi Surveyor Indonesia, 2018)

Sample Lable	A-1	A-2	A-3	A-4	A-5	APSN	INLET	OUTLET
T (°C) Air	26.4	26.2	26.5	26	26.2	84.2	24.6	24.8
T (°C) Udara	24.8	25.6	25.8	25.6	25.8	2.6.4	23.8	23.2
pH	2.72	2.73	2.74	2.83	2.71	5.21	6.78	2.78
TDS (mg/kg)	1181.976	1177.899	1169.967	1183.856	1220.038	198.118	1199.472	39402.046
Densitas (kg/L)	0.997	0.997	0.997	0.997	0.997	0.969	0.997	0.997
EC (µS/cm)	2360	2360	2360	2350	2340	42400	149	2300
Li (mg/kg)	0.482	0.482	0.492	0.492	0.502	25.900	0.000	0.491
Na (mg/kg)	263.797	226.821	228.916	217.699	253.118	10140.136	12.426	219.045
K (mg/kg)	16.917	18.281	19.155	17.457	17.658	1756.234	3.380	17.361
Ca (mg/kg)	74.521	82.463	74.533	78.355	78.480	2303.122	12.085	76.134
Mg (mg/kg)	8.468	9.833	9.362	9.100	9.652	27.654	4.824	9.317
SiO2 (mg/kg)	86.983	86.557	86.955	87.525	86.567	118.551	96.208	87.147
B (mg/kg)	19.355	19.735	19.737	19.734	19.735	428.183	0.181	20.079
Cl (mg/kg)	373.055	373.466	371.359	368.791	371.991	21033.739	6.007	365.135
F (mg/kg)	0.140	0.060	0.130	0.050	0.060	0.629	0.000	0.050
SO4 (mg/kg)	324.572	327.293	324.109	321.587	323.140	41.481	4.984	318.247
HCO3 (mg/kg)	0.000	0.000	0.000	0.000	0.000	56.753	77.354	0.000
CO3 (mg/kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NH4 (mg/kg)	0.843	0.963	1.054	1.013	1.274	16.923	0.090	0.582
As (mg/kg)	0.100	0.100	0.100	0.000	0.000	0.103	0.100	0.100
Rb (mg/kg)	10.074	9.251	9.332	10.003	9.863	0.000	0.000	0.000
Fe (mg/kg)	10.074	9.251	9.332	10.003	9.863	0.433	0.000	9.317
Mn (mg/kg)	0.943	0.783	0.943	0.943	0.783	47.373	0.000	0.883
meq. kation	18.690	17.559	17.205	16.527	18.603	1.632	16.788	607.903
meq. anion	17.289	17.353	17.231	17.102	17.225	1.541	16.929	595.189
% IB	3.894%	0.591%	-0.074%	-1.708%	3.846%	2.865%	-0.419%	1.057%

LAMPIRAN 2 Diagram Piper air panas bumi daerah penelitian



A) Persentasi Na+K-Ca-Mg

Nomor Sampel	%Na+K	%Ca	%Mg
APWS-1	85%	15%	0%
APWS-2	65%	32%	3%
APWS-3	66%	27%	7%
APWS-4	80%	14%	6%
AHN	95%	2%	3%
AHG	96%	2%	2%
ADS-1	89%	5%	5%
ADS-2	88%	6%	6%
ADS-3	88%	5%	6%
ADSA	37%	30%	32%
ADCR	38%	27%	34%
ADPI	15%	70%	15%
ADBO	60%	14%	25%
ADL-1	0%	0%	0%
ADL-2	0%	0%	0%
A-1	73%	23%	4%
A-2	68%	27%	5%

Nomor Sampel	%Na+K	%Ca	%Mg
A-3	70%	25%	5%
A-4	68%	27%	5%
A-5	71%	24%	5%
INLET	39%	37%	24%
OUTLET	69%	26%	5%
APSN	81%	19%	0%

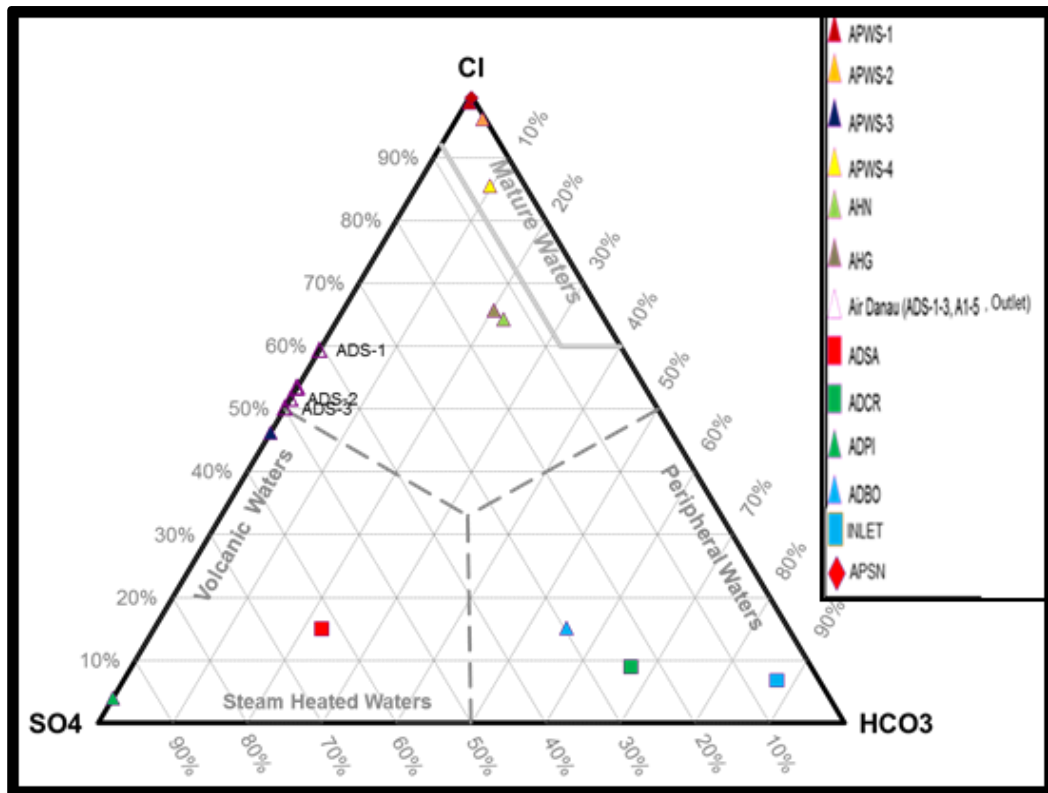
B) Persentasi Cl-HCO₃-SO₄

Nomor Sampel	%Cl	%HCO3	%SO4
APWS-1	99%	0%	1%
APWS-2	100%	2%	0%
APWS-3	54%	0%	46%
APWS-4	96%	6%	4%
AHN	87%	15%	11%
AHG	86%	13%	12%
ADS-1	66%	0%	34%
ADS-2	59%	0%	41%
ADS-3	58%	0%	42%
ADSA	25%	18%	62%
ADCR	34%	59%	27%
ADPI	5%	0%	95%
ADBO	41%	46%	32%
ADL-1	0%	0%	0%
ADL-2	0%	0%	0%
A-1	61%	0%	39%
A-2	61%	0%	39%
A-3	61%	0%	39%
A-4	61%	0%	39%
A-5	61%	0%	39%
INLET	62%	82%	7%
OUTLET	61%	0%	39%
APSN	100%	0%	0%

C) Persentasi Na+K-HCO₃

Nomor Sampel	%Na+K	%HCO₃
APWS-1	85%	0%
APWS-2	65%	2%
APWS-3	66%	0%
APWS-4	80%	6%
AHN	95%	15%
AHG	96%	13%
ADS-1	89%	0%
ADS-2	88%	0%
ADS-3	88%	0%
ADSA	37%	18%
ADCR	38%	59%
ADPI	15%	0%
ADBO	60%	46%
ADL-1	0%	0%
ADL-2	0%	0%
A-1	73%	0%
A-2	68%	0%
A-3	70%	0%
A-4	68%	0%
A-5	71%	0%
INLET	39%	82%
OUTLET	69%	0%
APSN	81%	0%

LAMPIRAN 3 Diagram Cl-SO₄-HCO₃ air panas bumi daerah penelitian

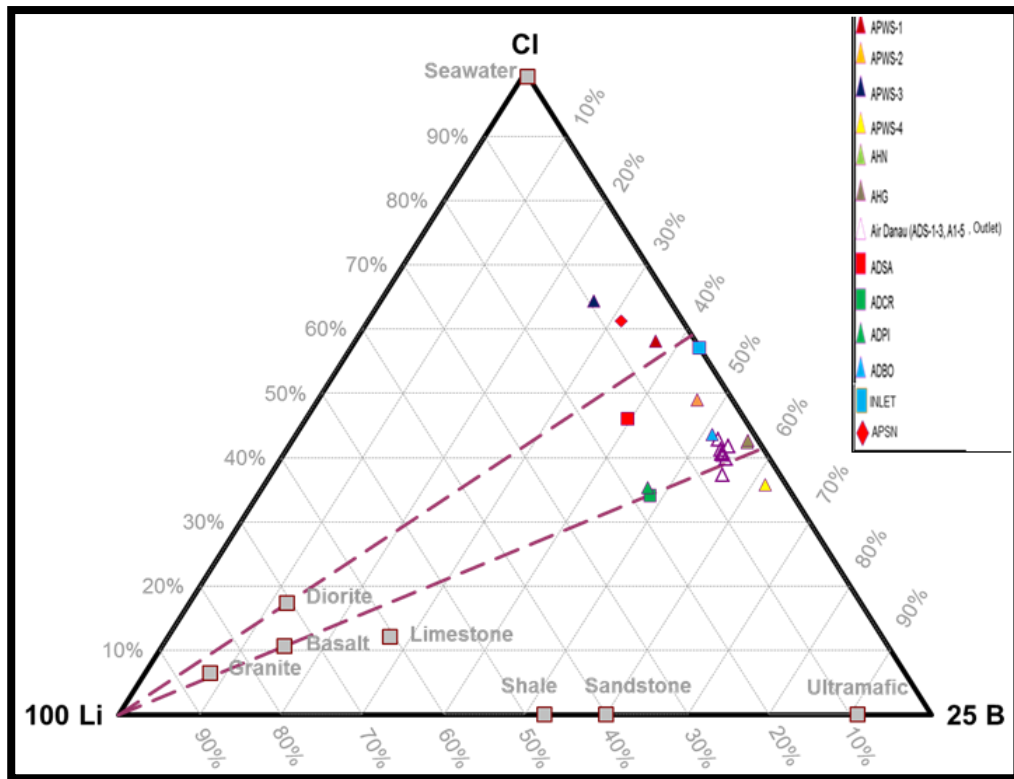


Persentasi CL-SO₄-HCO₃

Nomor Sampel	%Cl	%SO ₄	%HCO ₃
APWS-1	99%	1%	0%
APWS-2	96%	0%	3%
APWS-3	46%	54%	0%
APWS-4	86%	5%	10%
AHN	64%	14%	22%
AHG	66%	14%	20%
ADS-1	59%	41%	0%
ADS-2	52%	48%	0%
ADS-3	50%	50%	0%
ADSA	15%	63%	22%
ADCR	9%	24%	67%
ADPI	4%	96%	0%
ADBO	15%	30%	55%
ADL-1	0%	0%	0%
ADL-2	0%	0%	0%
A-1	53%	47%	0%
A-2	53%	47%	0%
A-3	53%	47%	0%

Nomor Sampel	%Cl	%SO4	%HCO3
A-4	53%	47%	0%
A-5	54%	46%	0%
INLET	7%	6%	88%
OUTLET	53%	47%	0%
APSN	100%	0%	0%

LAMPIRAN 4 Diagram Cl-Li-B air panas bumi daerah penelitian

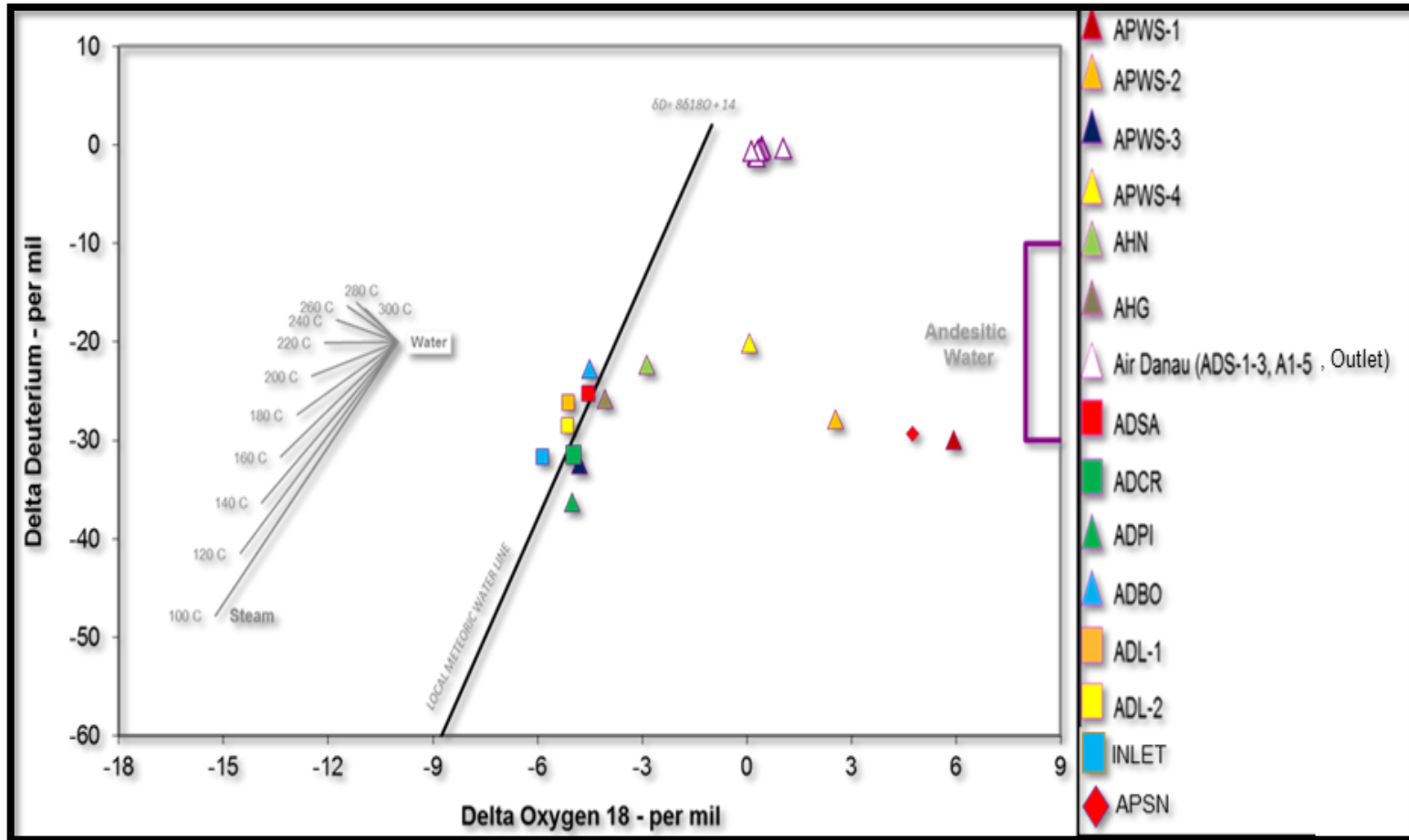


Persentasi Cl-Li-B

Nomor Sampel	%Cl	%Li	%B
APWS-1	58%	5%	37%
APWS-2	49%	4%	47%
APWS-3	64%	9%	26%
APWS-4	36%	3%	62%
AHN	42%	1%	56%
AHG	43%	1%	56%
ADS-1	42%	4%	54%
ADS-2	43%	5%	52%
ADS-3	37%	7%	56%
ADSA	46%	14%	40%
ADCR	34%	18%	48%
ADPI	35%	17%	47%
ADBO	44%	5%	51%
ADL-1	0%	0%	0%
ADL-2	0%	0%	0%
A-1	41%	5%	53%
A-2	41%	5%	54%
A-3	41%	5%	54%
A-4	40%	5%	54%

Nomor Sampel	%Cl	%Li	%B
A-5	41%	5%	54%
INLET	57%	0%	43%
OUTLET	40%	5%	55%
APSN	61%	8%	31%

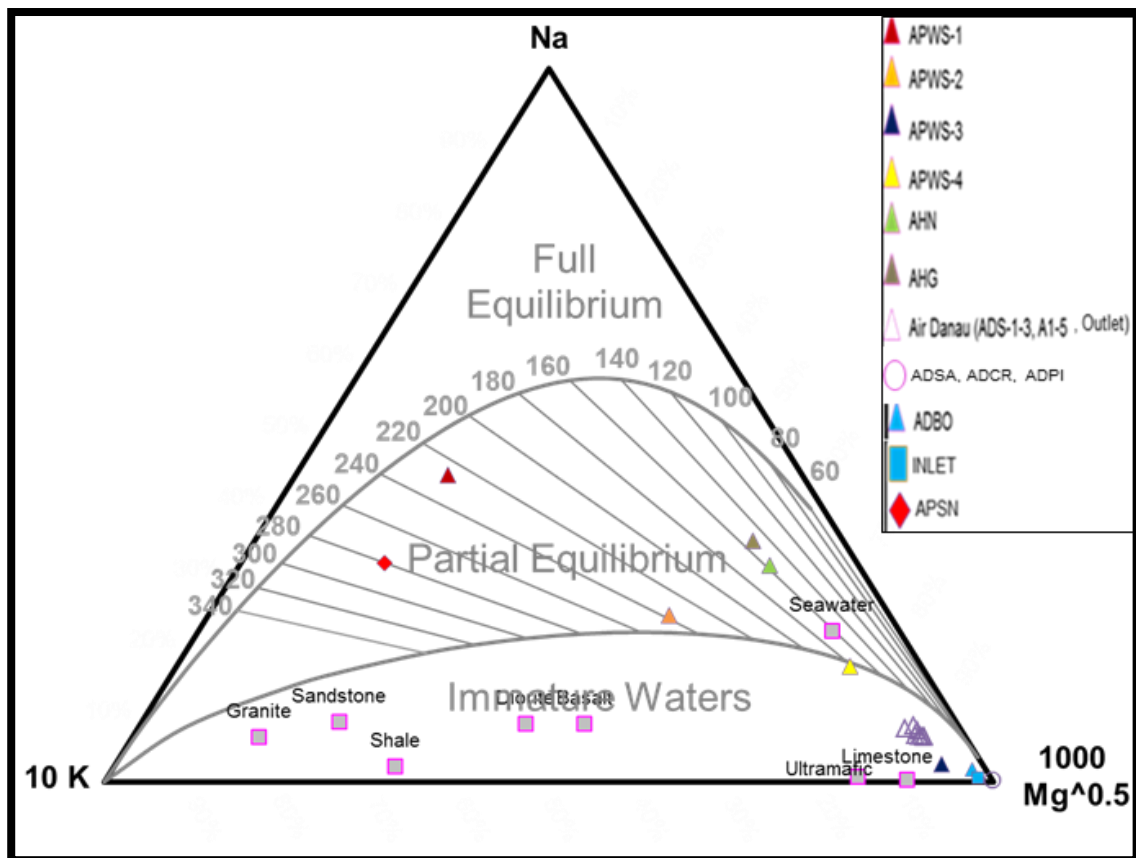
Lampiran 5 Diagram isotop ^{18}O dan ^2H air panas bumi daerah penelitian



Nilai isotop ^{18}O dan ^2H air panas bumi daerah penelitian

Nomor Sampel	Del 18O	Del D
APWS-1	5.93	-29.94
APWS-2	2.54	-27.86
APWS-3	-4.8	-32.4
APWS-4	0.07	-20.11
AHN	-2.87	-22.3
AHG	-4.07	-25.78
ADS-1	0.45	-0.15
ADS-2	0.44	-0.44
ADS-3	1.06	-0.39
ADSA	-4.55	-25.23
ADCR	-4.97	-31.5
ADPI	-5.01	-36.28
ADBO	-4.51	-22.72
ADL-1	-5.12	-26.16
ADL-2	-5.14	-28.51
A-1	0.26	-1.04
A-2	0.37	-0.61
A-3	0.28	-1.22
A-4	0.36	-0.48
A-5	0.31	-0.65
INLET	-5.86	-31.68
OUTLET	0.13	-0.64
APSN	4.75	-29.32

Lampiran 6 Diagram Na-K-Mg air panas bumi daerah penelitian



Persentasi Na-K-Mg

Nomor Sampel	%Na	%K	%Mg
APWS-1	43%	40%	17%
APWS-2	23%	25%	52%
APWS-3	3%	5%	93%
APWS-4	16%	8%	76%
AHN	30%	10%	60%
AHG	34%	10%	56%
ADS-1	7%	6%	86%
ADS-2	6%	5%	89%
ADS-3	6%	5%	89%
ADSA	0%	0%	100%
ADCR	0%	0%	100%
ADPI	0%	0%	100%
ADBO	2%	2%	97%
ADL-1	0%	0%	0%
ADL-2	0%	0%	0%
A-1	8%	5%	87%
A-2	6%	5%	88%

Nomor Sampel	%Na	%K	%Mg
A-3	7%	6%	88%
A-4	6%	5%	88%
A-5	7%	5%	88%
INLET	1%	2%	98%
OUTLET	6%	5%	89%
APSN	31%	53%	16%

Lampiran 7 Perhitungan kedalaman reservoir daerah penelitian

No.	Sampel	T. Manifestasi (°C)	T. Reservoir (°C)
1.	APWS-1	81,57	280
2.	APWS-2	71,13	226

1) Stasiun APWS-1

Diketahui:

$$T. \text{ Manifestasi } (T_0) = 81,57^\circ\text{C}$$

$$T. \text{ Reservoir } (T) = 280^\circ\text{C}$$

$$\text{Gradien Geothermal} = 15,2^\circ\text{C}/100 \text{ meter} = 152^\circ\text{C}/\text{km}$$

Ditanya:

Kedalaman reservoir (D)

Penyelesaian:

$$\begin{aligned} \text{Gradien Geothermal} &= (T-T_0)/D, \\ &= (280^\circ\text{C} - 81,57^\circ\text{C})/152^\circ\text{C} \\ &= 1,3042 \text{ km} \approx 1,3 \text{ km} \end{aligned}$$

Maka, kedalaman reservoir panas bumi daerah penelitian adalah 1,3 km.

2) Stasiun APWS-2

Diketahui:

$$T. \text{ Manifestasi } (^\circ\text{C}) = 71,13^\circ\text{C}$$

$$T. \text{ Reservoir } (^\circ\text{C}) = 226^\circ\text{C}$$

$$\text{Gradien Geothermal} = 15,2^\circ\text{C}/100 \text{ meter} = 152^\circ\text{C}/\text{km}$$

Ditanya:

Kedalaman reservoir (D)

Penyelesaian:

$$\begin{aligned}\text{Gradien Geothermal} &= (T-T_0)/D, \\ &= (226^\circ\text{C} - 71,13^\circ\text{C})/152^\circ\text{C} \\ &= 1,018 \text{ km} \approx 1 \text{ km}\end{aligned}$$

Maka, kedalaman reservoir panas bumi daerah penelitian adalah 1 km.

Lampiran 8 Perhitungan Potensi Panas Bumi daerah penelitian Metode Volumetrik

Data perhitungan sumber daya panas bumi daerah penelitian

$$\text{Luas} = 4 \text{ km}^2 = 4.000.000 \text{ m}^2$$

$$\text{Tebal} = 2.000 \text{ m}$$

$$t = 30 \text{ tahun}$$

$$T_i = 218,5 \text{ }^\circ\text{C}$$

Parameter Temperatur Sedang:

$$T_f = 120 \text{ C}$$

$$S_l = 80\%$$

$$R_f = 25\%$$

$$\emptyset = 10\%$$

$$\rho_r = 2650 \text{ kg/m}^3$$

$$C_r = 0.9 \text{ kJ/kg }^\circ\text{C}$$

$$\eta = 10 \%$$

Steam Table

$$U_l T_i = 934,04 \text{ kJ/kg}$$

$$\rho_l T_i = 842,14 \text{ kg/m}^3$$

$$U_v T_i = 2600,99 \text{ kJ/kg}$$

$$\rho_v T_i = 11,29 \text{ kg/m}^3$$

$$U_l T_f = 503,57 \text{ kJ/kg}$$

$$\rho_l T_f = 943,11 \text{ kg/m}^3$$

Prosedur perhitungan potensi panas bumi dengan metode volumetrik:

1. Menghitung energi di reservoir pada keadaan awal (kJ)

$$H_{ei} = A h ((1-\emptyset) \rho_{res} C_{res} T_i + \emptyset (\rho_l U_l S_l + \rho_v U_v S_v))$$

$$H_{ei} = (4 \times 10^6)(2 \times 10^3)((1-0,1) \times 2650 \times 0,9 \times 218,5 + 0,1(842,1 \times 934 \times 0,8 + 11,2 \times 2600,1 \times 0,2))$$

$$H_{ei} = (8 \times 10^9)(469.010,25 + 0,1(629.217,12 + 5824,224))$$

$$H_{ei} = 4,26 \times 10^{15} \text{ kJ}$$

2. Menghitung energi di reservoir pada keadaan akhir (kJ)

$$H_{ef} = A h ((1-\emptyset) \rho_{res} C_{res} T_f + \emptyset (\rho_l U_l S_l + \rho_v U_v S_v))$$

$$H_{ef} = (4 \times 10^6)(2 \times 10^3)((1-0,1) \times 2650 \times 0,9 \times 120 + 0,1(943,1 \times 503,5 \times 1))$$

$$H_{ef} = (8 \times 10^9)(257.580 + 0,1(474.850,85))$$

$$H_{ef} = 2,44 \times 10^{15} \text{ kJ}$$

3. Menghitung energi yang dapat diambil (kJ)

$$H_{th} = H_{ei} - H_{ef}$$

$$H_{th} = 4,26 \times 10^{15} \text{ kJ} - 2,44 \times 10^{15} \text{ kJ}$$

$$H_{th} = 1,86 \times 10^{15} \text{ kJ}$$

4. Menghitung energi yang dapat dimanfaatkan (kJ)

$$H_{de} = Rf \times H_{th}$$

$$H_{de} = 0,25 \times 1,86 \times 10^{15} \text{ kJ}$$

$$H_{de} = 4,6 \times 10^{14} \text{ kJ}$$

5. Menghitung potensi panas bumi (MWe)

$$H_{thermal} = (H_{de} \times \eta) / (t \times 365 \times 24 \times 3600)$$

$$H_{thermal} = 4,6 \times 10^{14} \text{ kJ} \times 0,1 / (30 \times 365 \times 24 \times 3600)$$

$$H_{thermal} = 48 \text{ MWe}$$

Maka, besar sumber daya panas bumi daerah penelitian adalah sebesar 48 MWe.

