Identification of water origin model in the West Tompaso Minahasa, North Sulawesi, Indonesia

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Abstract. Sixteen water samples were collected from the river, spring, and hot spring at the West Tompaso in Minahasa Region, North Sulawesi, Indonesia. The water types were identified as Ca-HCO₃, Ca-SO₄, Na-HCO₃, Na-SO₄, and H-SO₄. The samples water of TS-1, TS-02, TS-03, TS-04, WT-11, and T-12 are Ca-HCO₃ type. The origin of this water type is shallow groundwater. Another water samples of TS-05, TS-06, TS-07, GS-13, GS-14, and GS-15 are Ca-SO₄ type. These water types were identified as hot springs. Two samples of water of WT-10 and WT-16 are Na-HCO₃ type. These waters come from the confined aquifer. The sample water of BK-08 is Na-SO₄ type. This water is saline affected water and comes from the hot spring. BK-9 is H-SO₄ type. This water type is steam-heated water and rich acidic water. All samples of water origin are shallow groundwater and surface water. Shallow groundwater model at the West Tompaso was developed.

1. Introduction
According to the development of geothermal energy power (PLTP) units 5 and 6 projects in the West Tompaso Minahasa Region, it is a great concerned to the local people. The local people were suggested to the company about this development project that will give the impact to the source of water in Tonsewer, Touure, Pinabetengan and Kanonang villages [1]. The study area is shown in figure 1. Source water in these villages would be decreasing or disappear after this project operated. Water is very important for the local people to irrigate the horticulture plantation. This research aims to identify origin of water in the West Tompaso. The origin of water to describe the water comes from, trip of water, chemical reaction when touched with the lithology, and affected with the temperature from geothermal. All steps of this water trip can be interpretive to make the model of shallow groundwater system in the West Tompaso. The result of this study will explain the water originate as water come from the geothermal reservoir or shallow groundwater system. Local people in the West Tompaso are rejecting this project if source waters in this village are originated from geothermal reservoir. The study area in West Tompaso has included four villages among of Pinabetengan village, Touure village, Tonsewer village, Kanonang village, as shown in figure 1.

2. Geology and structure setting

2.1. Geological setting
The study area locates in West Tompaso mainly lies at Kanonang, Pinabetengan, Toure, Tonsewer villages. The lithology consists of the Tertiary and the Quaternary rocks. Tertiary sedimentary rocks consist of shale and sandstone with intercalation of limestone and chert and are overlain by Tertiary
and Quaternary volcanic rocks. Tertiary volcanic rocks are products of Old volcano consisting of breccia, tuff, and lava. Young volcanic rocks (Qv), Tufa Tondano (Qtv), and Lacustrine and fluviatile deposits (Qs) overlain the Tertiary volcanic rocks (TMV) in West Tompaso. Tertiary volcanic rocks mainly composed of breccia, lava, and tuff [2,3]. The lava flows generally are andesitic to basaltic. Young volcanic rocks consist of lava, bom, lapilli, and ash. These volcanic rocks are to form the young stratovolcano such as Soputan Mountain. Coarse volcanic clastic of Tufa Tondano consist of andesitic composition with angular to subangular components characterizes by abundant pumice fragment, tuff, lapilli tuff breccia. It is very dense ignimbrite with flow structure. Lacustrine and fluviatile deposits consist of sand, silt, conglomerate, and mainly clay.

2.2. Structure setting
Fault in the West Tompaso had three directions northeast (NE) to southwest (SW), five directions northwest (NW) to southeast (SE), east (E) to west (W), and north (N) to south (S). Fractures with direction NE to SW are crossing Young volcanic rocks, Tufa Tondano and Lacustrine, and fluviatile deposits that lay the area of Pulutan, Tolok Satu, Liba, Kamanga Dua, Tonsewer Selatan, Touure Dua, Touure Satu villages. Faults with direction NE to SW are crossing Young volcanic rocks, Tufa Tondano and lies the area of Kanonang Dua, Pinabetengan Selatan, Tompaso Dua, Pinaesaan, Talikuran, Sendangan, Kamanga Dua, Tondegesan Satu, Tempok Selatan, Tempok, Liba, Kamanga,
Taraitak Satu, Paslaten, Kanonang Empat villages. Fracture with direction NE to SW is crossing Young volcanic rocks, Tufa Tondano and lays the area of Kanonang Dua, Pinabetengan Selatan, Tomposo Dua, Pinaesaan, Talikuran, Sendangan, Kamanga Dua, Tondegesan Satu, Tempok Selatan, Tempok, Liba, Kamanga, Taraitak Satu, Paslaten, Kanonang Empat villages. Fracture with direction east to west is crossing Young volcanic rocks, Tufa Tondano and Lacustrine, and fluviatile deposits that lay the area of Tonsewer Selatan, Touure Dua, Tumaratas Satu, Taraitak villages. One fault with direction north to east is crossing Young volcanic rocks that lays area of Kanonang Satu, dan Kanonang Dua villages. Figure 2 shows the location of samplings and geological surface and structure map.

3. Sampling and methodological analysis

All samples were collected in a 250 ml polypropylene bottle after filtrating using 0.45µm membrane filter. Water temperature, Electric conductivity (EC) and pH were measured on-site by portable instruments. The anion (F, Cl, Br, NO₃, PO₄, and SO₄) and cation (Li, Na, NH₄, K, Mg, and Ca) were analyzed using ion chromatography system (Dionex ICS-90). Bicarbonate (HCO₃⁻) was measured using the titration method at laboratory in Kyushu University. Concentrations of SiO₂ and Fe total were measured by spectrophotometer (Hitachi U 1800) using the molybdate yellow method and the 1, 10-phenanthroline method, respectively. The quality of the analysis was evaluated using the ion balance (IB) between anion and cation, as the follow equation:

\[
IB(\%) = \frac{\sum \text{Cations (meq./L)}}{\sum \text{Cations (meq./L)}} - \frac{\sum \text{Anions (meq./L)}}{\sum \text{Anions (meq./L)}} \times 100
\]

The water type was analyzed using the piper diagram as shown in figure 3. A piper diagram is a graphical representation of the chemistry of a water sample or samples. The cations and anions are shown by separate ternary plots. The apexes of the cation plot are calcium, magnesium, and sodium plus potassium cations. The apexes of the anion plot are sulfate, chloride, and carbonate plus hydrogen carbonate anions [5]. The two ternary plots are then projected onto a diamond. The diamond is a matrix transformation of a graph of the anions (sulphate + chloride/ total anions) and cations (sodium + potassium/total cations).
4. Result and discussion
Water samples at sixteen locations were collected from hot springs, springs, and rivers in the area 4 km N-S and 5 km E-W of West Tomposo. Elevation of sampling sites ranges from 802 m, TS-7, on Tonsewer village up to 1.309 m of above sea level (GS-13) on Sempu Mountain. The results of chemical analyses of water samples were controlled by ion balanced. All analyses reported in this study have IB<13%, excluding acidic samples. A piper diagram was used to evaluate the characteristic of chemical water and to identify the water type as shown in figure 3.

![Piper Diagram](image)

**Figure 3.** Chemical analyses of water samples.

| SOURCE/SAMPLE NAME | CODE | LOCATED | WATER TYPE | TEMPERATURE (°C) | ELEVATE (m) | ORIGIN OF WATER |
|--------------------|------|---------|------------|------------------|-------------|-----------------|
| SPRING LEPA        | TS-1 | TS-1    | CaHCO₃     | 22.1             | 996         | SHALLOW GRAUNDWATER |
| SPRING WELEN MEONG | TS-2 | TS-2    | CaHCO₃     | 22.3             | 994         | SHALLOW GRAUNDWATER |
| SPRING PANASEN     | TS-3 | TS-3    | CaHCO₃     | 23.8             | 829         | SHALLOW GRAUNDWATER |
| SPRING SEPET       | TS-4 | TS-4    | CaHCO₃     | 23.7             | 800         | SHALLOW GRAUNDWATER |
| SPRING SOPUTAN, WELEN MEONG | TS-5 | TS-5 | CaSO₄     | 22.3             | 994         | HOT SPRING |
| SPRING WELEN MEONG | TS-6 | TS-6    | CaSO₄     | 33.9             | 813         | HOT SPRING |
| SPRING PASO        | TS-7 | TS-7    | CaSO₄     | 35.5             | 802         | HOT SPRING |
| HOT SPRING BUKIT KASHI | BK-8 | BK-8 | NaHCO₃     | 95               | 890         | SALINE HOT SPRING |
| HOT SPRING BUKIT KASHI | BK-9 | BK-9 | HSO₄      | 97               | 893         | STEAM HEATED WATER |
| DRAINASE WATUPINABETENGAN | WT-10 | WT-10 | NaHCO₃ | 45.5             | 905         | CONFINED AQUIFER |
| SPRING BUKIT KASHI | WT-11 | WT-11 | CaHCO₃ | 18.9             | 915         | SHALLOW GRAUNDWATER |
| RIVER PANASEN      | T-12 | TONSEWER | CaHCO₃ | 26.1             | 862         | SHALLOW GRAUNDWATER |
| SPRING GUNUNG SEMPU | GS-13 | GS-13 | CaSO₄ | 21.4             | 1309        | HOT SPRING |
| SPRING GUNUNG SEMPU | GS-14 | GS-14 | CaSO₄ | 20.5             | 1279        | HOT SPRING |
| SPRING GUNUNG SEMPU | GS-15 | GS-15 | CaSO₄ | 23.4             | 951         | HOT SPRING |
| HOT SPRING WATUPINABETENGAN | WT-16 | WT-16 | NaHCO₃ | 54               | 936         | CONFINED AQUIFER |

**Table 1.** Water type and origin of water at the West Tomposo.
The water type was characterized using the piper diagram into five groups of Ca-HCO₃, Ca-SO₄, Na-HCO₃, Na-SO₄, and H-SO₄ as shown in table 1. Water samples of TS-1, TS-02, TS-03, TS-04, WT-11, dan T-12 are Ca-HCO₃ type and to identify as shallow groundwater. Other water samples of TS-05, TS-06, TS-07, GS-13, GS-14, and GS-15 are Ca-SO₄ type and to originate as hot spring. Water samples of WT-10 and WT-16 are Na-HCO₃ type and to categorize as confined aquifer. The water sample of BK-08 is Na-SO₄ type. This water is hot spring and saline affected water. In the trip of water has been through alkali of lithology and heating in the deep of ground before discharge to the surface at the lower elevation. The water sample of BK-09 is H-SO₄ type and to indicate as steam-heated water and rich acidic water. This water originates from boiling of water in the deep of ground that contains H₂S going up and reacting with rich oxygen surface water and discharge to the surface as high-temperature acidic water (>90°C). The model of shallow groundwater and surface water in West Tompaso was developed and shown in figure 4.

5. Conclusion
These sixteen water samples were collected from river, spring, and hot spring in the Pinabetengan, Toure, Tonsewer, and Kanonang village in the West Tompaso in Minahasa Region, North Sulawesi, Indonesia. The water types in West Tompaso were identified as Ca-HCO₃, Ca-SO₄, Na-HCO₃, Na-SO₄, and H-SO₄. All water samples of TS-1, TS-02, TS-03, TS-04, TS-5, TS-6, TS-07, BK-08, WT-10, WT-11, T-12, GS-13, GS-14, GS-15, and T-16 are identified as surface water and shallow groundwater. This water has trip from the rain going to surface and continue infiltrate into ground and passing in the shallow or deep in the ground and through the unconfined or confined aquifer before discharge to the surface at the lower elevation. Another water, when through in the deep of ground, received heating from natural geothermal and discharge with high temperature to the surface as hot spring. Sources water in Pinabetengan, Toure, Tonsewer, Kanonang village origins are also identified shallow groundwater and surface water. Furthermore, shallow groundwater model at the West Tompaso was developed.
References

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