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THE SPRINGS PHENOMENA AS CONTACTS BOLDER MARKER BETWEEN NANGGULAN AND OLD ANDESITE FORMATIONS AT THE EASTERN PART OF KULON PROGO DOME, INDONESIA

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ABSTRACT: Nanggulan Formation located in the eastern part of Kulon Progo Dome that situated on weakly undulated morphology with the elevation difference of 45 meters, the slope of 20.34%, and consisted of impermeable clastics sedimentary rocks. The Old Andesite Formation that is surrounding reflected that the steeply hills morphology with an elevation difference of 89.09 meters, the slope of 40.07%, and the permeable volcanic rocks. The research area is located in the eastern part of Kulon Progo Dome, included in Kulon Progo Regency. Springs are generally rising in between contact of Nanggulan Formation and Old Andesite Formation. These condition has become an interesting problem to study further. The purpose of this research is to understand the presence of springs. Whereas the aim of this research to determining morphology, lithology, and structural geology toward the presence of the springs. The research methods used by field observation and gravity measurement. The pattern of springs distribution not always follow in valley lineaments. The result of gravity measurement showed that the presence of springs around the Mujil traverse controlled by fault contact and stratigraphy contact. In contrast, of springs on the Sentolo traverse was controlled by stratigraphy contact. Springs controlled by fault, followed by valley lineament. The presence of springs due to stratigraphy contact occurred in contact with the permeable and impermeable rock. The presence of spring due to stratigraphy contact could use as a preliminary indication of the existence of contact of Nanggulan Formation and Old Andesite Formation.

Keywords: Springs, gravity, contact, stratigraphy, fault

1. INTRODUCTION

Old Andesite Formation that widespread in Kulon Progo Mountain consists of volcanic rocks [1]. In the Old Andesite Formation, Kebobutak Formation comprised of andesite breccia, tuff, lapilli tuff, agglomerates, and intercalation of lava [2]. The volcanism activity in Kulon Progo Mountain occurred in Late Oligocene–Middle Miocene [3]. Volcanism activity in Kulon Progo occurred in three stages with indicated the presence of three ancient volcanoes such as Gajah Mountain, Ijo Mountain, and Menoreh Mountain. Based on the total of lineaments, on Gajah Mountain, as the oldest volcano has 430 lineaments, Ijo Mountain has 345 lineaments, and Menoreh Mountain has 249 lineaments. Generally, the direction of lineaments is South East-North West [4]. By many lineaments caused the rocks to become more permeable.

Old Andesite Formation overlaid unconformity on Nanggulan Formation that well exposed in the eastern part of Kulon Progo Dome and contact to rock volcanic as a result of Gajah Mountain [4]. Nanggulan Formation consists of sandstone, shale with large and small foraminifera, and marl [5]. Based on rock variation, the Nanggulan Formation has more impermeable rock characteristics. The distribution of Nanggulan Formation placed on weakly undulated hills, whereas the Old Andesite Formation was on steep hills. On weakly undulated hills are used for urban settlements and agricultural land use. On the steep, undulated hills are used for farm, forest, and a few settlements. Contact of Nanggulan Formation and Old Andesite Formation is structural contact of thrust fault with the direction of North East-South West that caused the Nanggulan Formation was outcropped on the surface [4].

By the increase of clean water needs, some inhabitants used the springs to fulfill the daily need, due to the water from dug wells could not be enough. Generally, the springs emerge in between Nanggulan Formation and Old Andesite Formation. The objective of this research is to reveal the factors that caused the presence of springs in the research area. The purpose of this research is to

understand the presence of springs from the geological aspect. The aim of this research is also to determining morphology, lithology, and structural geology toward the presence of those springs.

2. GEOLOGY AND HYDROGEOLOGY OF THE KULON PROGO AREA

The Kulon Progo Mountain is an eastern part of South Serayu Mountain with the dome shape [1]. The morphology characterized by steep hills and its surroundings characterized by low hills. These morphological differences could cause by lithology difference.

Stratigraphy of the Kulon Progo comprised of some rock formations with the sort from oldest to youngest formation. Such as Nanggulan Formation, Old Andesite Formation, Jonggrangan Formation Sentolo Formation, and Quartenary unconsolidated sediments [1][2][6][7][8][9].

Nanggulan Formation has age in Middle Eocene to Oligocene [1][10][11][12][13], and Middle Eocene to Early Upper Eocene [14]. Nanggulan Formation divided into Kalisonggo members on the lower part and Seputih member on the upper part [5].

The result of age identification in volcanic rock with an isotope of 40K-40Ar showed that Old Andesite Formation formed from volcanism activity that occurred in Late Oligocene to Middle Eocene [3]. Old Andesite Formation divided into two groups, such as Kaligesing Formation and Dukuh Formation [5].

The Kaligesing Formation, which formed the moderate undulated morphology to steep undulation morphology, consists of monomic breccia with andesite fragment, sandstone, and lava. Dukuh Formation formed the weak to moderate undulated morphology was consisted of polymics breccia, andesite breccia, and sandstone. Based on morphology and rock association, the research area included in Dukuh Formation.

The geoelectrical study on Nanggulan Formation to the depth of 120 meters dominated by shale and tuffaceous sandstone with local distribution; by this case, the presence of aquifer in Nanggulan Formation is limited [15].

The lower part of the Jonggrangan Formation consists of calcareous tuff, Mollusca sandstone, shale with intercalation of lignite, and the upper part is consisted of bedded limestone, and coral limestone has aged in Early Miocene to Middle Miocene. It mapped on the center of Menoreh Mountain-Gajah-Ijo, formed as a conical hill [4]. In Jonggrangan Formation has springs that formed by lineaments or fractures. The distribution of springs and lineaments or fractures has the same direction as North East-South West [16]. Sentolo Formation is consisted of limestone and calcareous shale and has an interfingering relationship with Jonggrangan Formation [4].

The Wates groundwater basin divided into two groups, such as the Tersier Formation (Kebobutak Formation and Sentolo Formation) as the basement of The Wates groundwater basin and Quartenary Formation (alluvial and volcanic sediments of Young Merapi) as sediment filling of groundwater basin [17]. Generally, the recharge area in The Wates groundwater basin was on the elevation of 15 meters to 25 meters above sea level, located in the north part. In contrast, the discharge area was on the elevation of 15 meters to 0 meters above sea level, located in the south part [17].

3. THEORY

3.1 Spring

Groundwater is subsurface water located in the rock layer as an aquifer. Springs place for groundwater that emerged in the surface caused by the groundwater flows was cut by nature phenomenon until groundwater could emerge on the surface [18].

Based on hydraulic pressure in an aquifer, springs divided into two, such as artesian and gravity [19]. Artesian springs emerged caused by hydraulic pressure from the subsurface that could flow up at the same level as a piezometric surface without any pumping. The characteristic is sustainable due to the long distance of recharge and discharge. Gravitational springs emerge were not caused by pressure and horizontal flow direction.

The kind of these springs divided into three such as depression springs, contact gravity springs, and joint springs. Depression springs emerge due to groundwater-surface were cut by topography and included in shallow groundwater type. Contact gravity springs emerge due presence of contact between permeable and impermeable layer; also, the groundwater-surface cut by topography.

Contact of both layers occurred caused by stratigraphy or structural geology. Contact of springs generally occurred in an unconfined aquifer or shallow groundwater system. The turbulence groundwater is a spring caused by the presence of fractures on the permeable zone or joints on rugged rocks with low permeability. The groundwater generally formed when the groundwater flow cut by a break of slope.

3.2 Gravity

The gravity method usually used to determine for basement margin, distribution, thickness, and structural geology based on a variation of density. The physics law that likely to be essential for

gravity method development is Newton law [20], whereas the value of Bouguer anomaly obtained as an equation [21]:

$$\Delta gB = gm + (\Delta gFA - \Delta gBP + \Delta gT + \Delta gtide) - \Delta gn \quad (1)$$

With ΔgB is Bouguer gravity anomaly, gm: the result of data observation, ΔgFA: gravity value of free air correction, ΔgBP: gravity value of Bouguer correction, ΔgT: gravity value of topography correction, Δgtide: gravity value of tidal correction and Δgn: gravity value of mathematics calculation.

The value of Simple Bouguer Anomaly correction (ΔgBA) is an addition of gravity value of observation data with elevation correction (gElev.) than diminished by theoretical gravity value (gϕ) [22], the density value average was set as 2.7 gr/cm^3 with correction factor about 0.1967 mgal/meter.

$$\Delta gBA = gobs. + gElev. - g\phi \quad (2)$$

The value of Quartenary aluvium gravity Bantul regency is 2.0-2.27 gr/cm^3, limestone gravity value is 2.5 gr/cm^3 and igneous rocks is 2.73-2.80 gr/cm^3 [23]. Kulon Progo area has a high gravity value about +50 to +145 mgal with the basement density value is about 2.8 gr/cm^3 that showed in depth of 3000 to 4000 meters, intrusion rock density is about 2.79 gr/cm^3 and sedimentary rock density is about 2.5 gr/cm^3 [24].

4. METHODS

In this research, the surface identification of the location and lithology of the spring. Morphometrical measurement, and subsurface identification with measured gravity value. The morphometric measurements, especially in valley lineaments, were conducted in Clumprit River, Klepu River, and Kalisonggo River, whereas on steep hills identified by Shuttle Radar Topography Mission image. The gravity measurements done in two traverses, such as Mujil dan Sentul traversed with measurements total of 47 points.

The research area located in the eastern part of Kulon Progo Dome. Administratively, it included in Nanggulan and Girimulyo Sub-District, Kulon Progo Regency, Yogyakarta Special Region (Fig. 1).

5. RESULT AND DISCUSSION

The morphological research area divided into two, such as steep hills and weakly undulated hills (Fig. 2). On steeply hills were characterized by angular morphology with the elevation differences of 89.09 meters and slope averages of 40.07%, also steeply river stream. This morphology consists of Old Andesite Formation. On the weakly undulated hills were characterized by elevation differences average of 45 meters and slope average of 20.34% also the wide and has meanders. On this morphology was consisted of Nanggulan Formation.

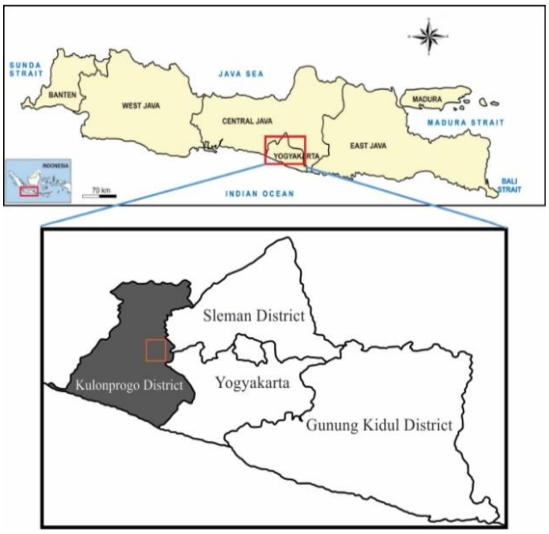

Fig. 1 Research area is in the administrative area of the Kulon Progo Regency.

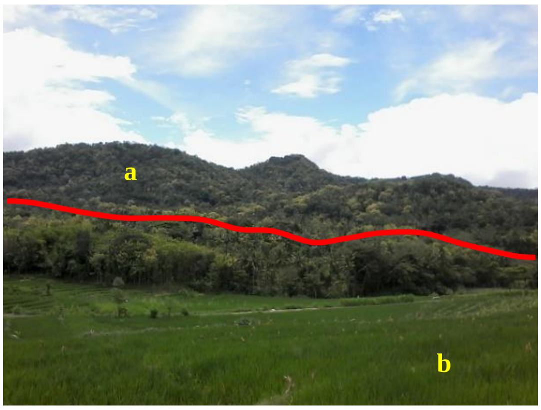

Fig. 2 Morphological research area a). Steeply hills, b). weakly undulated hills.

Nanggulan Formation consists of sandstone, quartz sandstone, intercalation of lignite, claystone, and calcareous claystone. The abundance of sandstone and claystone is more dominantly than other rocks. Generally, Nanggulan rock formation is impermeable. In the Old-Andesite Formation dominated by andesite breccia. On someplace was founded by the andesitic intrusion and andesitic lava. Those rock has many fractures, caused the rock to become permeable. Rock variation of Nanggulan Formation and Old Andesite Formation in Fig. 3.

In the research area, nine spring locations were identified from the largest at the north side to the

south side (Table 1). Springs generally founded at an elevation of 127 to 227 meters that emerged in between contact of andesite breccia and claystone.

One of the spring locations is in di Sentul Village (Fig. 4). Those springs emerge in permeable claystone and right on andesite breccia with many fractures. That breccia is more permeable.

Valley lineament is a character of the presence of a weak zone caused by tectonics that springs emerge followed the valley lineaments pattern. The result of valley lineament measurements (Fig. 5) determined that the distribution of springs is not followed by the valley lineaments pattern, even in some springs on the north side were not emerge on the valley.

If the distribution of the spring positioned on the geological map (Fig. 6), the springs would emerge in between contact of Nanggulan Formation and Old Andesite Formation. The subsurface geological condition depicted on the geological cross-section of A-A' and B-B' (Fig. 7 a & b).

Fig. 3a). Interbedded of sandstone and claystone in Nanggulan Formation, b). Fractures in Andesitic easily found more.

Fig. 4 Springs in Sentul Village emerge in between impermeable and permeable.

The gravity measurement in Mujil and Sentul traversed were data obtained in (Table 2). Gravity traverst（Fig. 8）was made to pass some springs locations, with the purpose of springs condition toward the local geological condition.

Table 1 Identification of springs location

No.	Location	Elevation (m)	Lithology
1	Sentul Village	183	Claystone
2	Kalisonggo Village	128	Claystone
3	Tempel Village	153	Andesite breccia
4	Kepek Village	215	Andesite breccia
5	Watumurah River	199	Andesite breccia
6	Klepu River	227	Andesite breccia
7	Kalisonggo River	132	Andesitic intrusion
8	Ngentak Village	127	Sandstone
9	Tileng Village	140	Andesite breccia

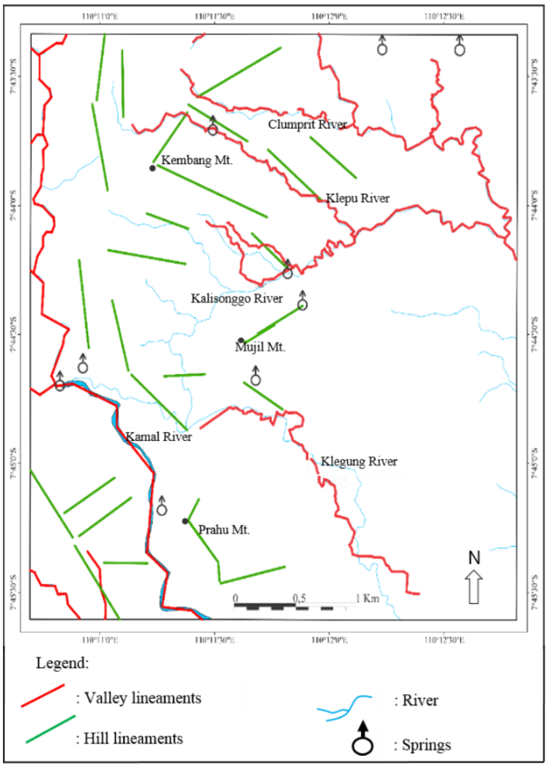

Fig. 5 The distribution pattern was not related to valley lineaments pattern.

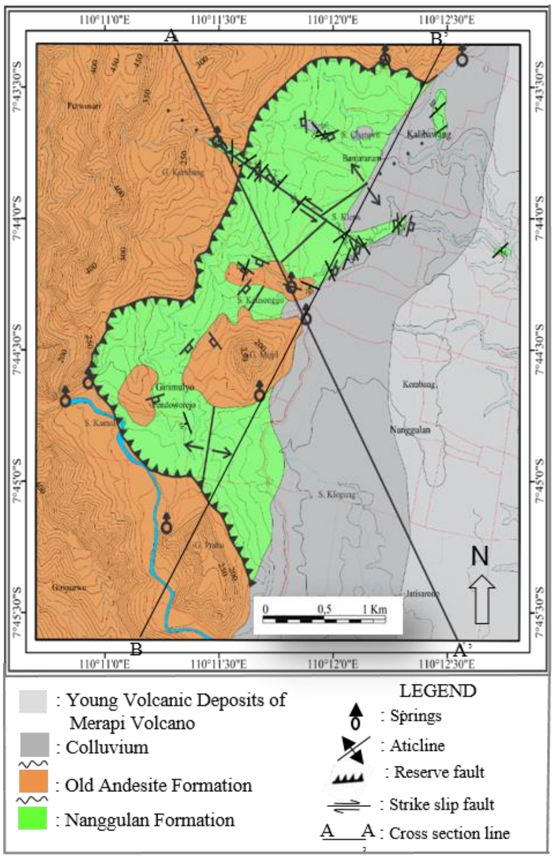

Fig. 6 The distribution of springs on the geological map.

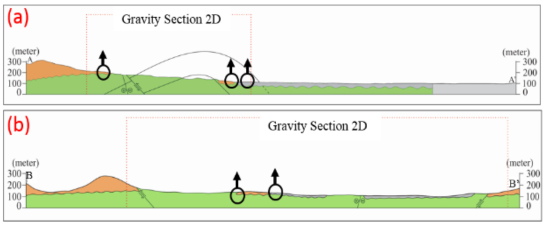

Fig. 7 The position of springs on geological cross-section (a) Mujil cross-section of A-A' and (b) Sentul cross-section of B-B'.

The result of gravity processing on Mujil traversed (Fig. 9) reflected that the presence of springs could cause by two factors such that one springs emerged in around the fault zone, and two springs emerged in contact of rock formation. Processing of gravity measurement on Sentul traverse (Fig. 10) depicted that two springs emerge in around the contact of rock formation.

Table 2 The result of gravity measurements.

Location	Time	Reading	Elevation (m)
Base	12:44:04	1866.44	139.17
G1	16:10:17	1821.35	159.74
G4	16:28:25	1824.85	173.24
G6	16:45:29	1824.70	151.33
G7	17:09:55	1827.27	140.96
G10	17:26:01	1830.84	126.07
Base	17:49:30	1828.85	139.17
Base	08:26:28	1828.79	139.17
G9	09:00:19	1829.90	129.49
G8	09:25:36	1826.03	145.02
G5	09:49:41	1821.85	162.77
G3	10:21:46	1820.62	164.87
G2	10:55:19	1812.59	198.74
G12	15:55:20	1832.07	144.11
G11	16:19:34	1832.98	139.57
Base	19:14:30	1833.26	139.17
Base	08:21:06	1833.27	139.17
G47	12:33:31	1809.60	241.80
Base	17:33:34	1833.31	139.17
Base	08:43:20	1833.18	139.17
G14	09:38:00	1833.04	139.39
G15	09:13:40	1833.92	135.11
G13	10:05:20	1831.22	147.99
G16	10:30:00	1832.57	143.87
G44	14:13:00	1814.57	223.10
G45	14:42:00	1810.45	238.45
G46	15:33:00	1805.70	261.19
G43	16:06:40	1809.65	246.27
G42	16:34:20	1814.13	226.73
G41	16:57:40	1818.58	207.52
Base	17:58:00	1833.20	139.17
Base	08:31:03	1832.81	139.17
G18	09:09:41	1834.10	143.04
G21	09:33:28	1834.82	142.03
G20	09:59:59	1834.15	145.16
G36	10:25:42	1830.90	158.23
G37	10:49:20	1829.90	164.06
G38	11:12:57	1823.19	191.30
G39	11:35:56	1819.55	206.68
G40	13:45:51	1827.19	169.85
G19	14:45:54	1833.73	142.58
G17	15:05:56	1833.03	144.38
Base	16:35:52	1832.72	139.17
Base	07:45:17	1832.80	139.17
G35	09:21:00	1832.90	151.13
G23	13:27:13	1829.34	167.34
G24	14:01:20	1820.05	210.69
G28	14:28:34	1826.08	183.64
G27	15:01:01	1833.50	154.55
G26	15:25:48	1833.61	152.81
G25	15:49:44	1834.52	146.96
G22	16:18:00	1835.51	140.26
Base	16:53:22	1832.81	139.17
Base	10:27:35	1824.52	139.17
G34	14:18:52	1814.40	207.10
Base	17:16:33	1824.58	139.17
Base	08:04:45	1824.35	139.17
G33	09:20:48	1820.40	181.38
G30	13:58:00	1827.34	147.16
G29	14:20:31	1820.86	173.66
G32	16:44:09	1821.67	173.90
G31	17:06:55	1824.52	160.78
Base	17:51:35	1824.38	139.17

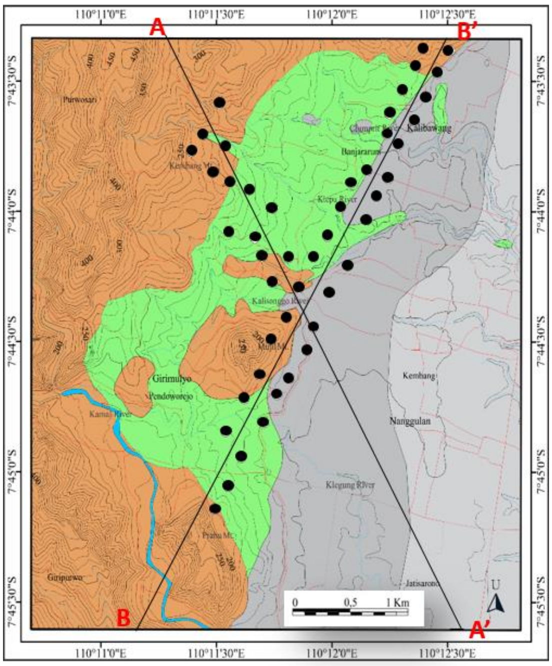

Fig. 8 The gravity measurement by the point.

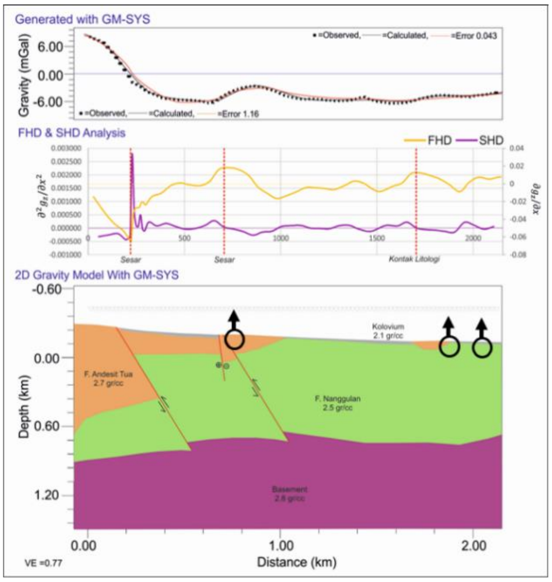

Fig. 9 Mujil traversed gravity cross-section (A-A').

6. CONCLUSION

The springs distribution does not always follow by valley lineaments pattern. In some places, the presence of springs not followed by the presence of the valley. The distribution of springs that reflected on the geological map followed the pattern of contact of Nanggulan Formation and Old Andesite Formation. Nanggulan Formation is consisted of impermeable rocks, whereas the Old Andesite Formation has consisted of permeable rocks.

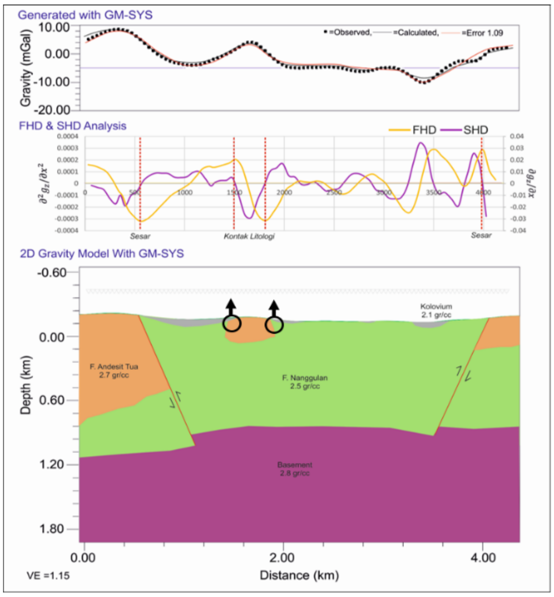

Fig. 10 Gravity cross-section on Sentul traversed (B-B').

A thrust fault identified gravity data measurement on Mujil traverse. Those faults caused the springs formed. On the other side, in the eastern part of the research area, the springs emerge controlled by stratigraphy contact. On Sentul traverse, the stratigraphy contact could be the central control in the presence of springs. This condition gives evidence that the presence of springs could control by structural geology and stratigraphy contact. Springs that emerge caused by structural would follow by valley lineaments pattern. Springs that emerge due to stratigraphy contact in between impermeable rocks (Nanggulan Formation) and permeable rocks (Old Andesite Formation) could indicate that the presence of springs would found on the margin of both formations.

7. ACKNOWLEDGMENTS

This research was supported by Institut Teknologi Nasional Yogyakarta and The Ministry of Research and Technology of the Republic of Indonesia, who gave funds and opportunity. Thank all the field teams, which help to gain the observation data.

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THE SPRINGS PHENOMENA AS CONTACTS BOLDER MARKER BETWEEN NANGGULAN AND OLD ANDESITE FORMATIONS AT THE EASTERN PART OF KULON PROGO DOME, INDONESIA

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ABSTRACT: Nanggulan Formation located in the eastern part of Kulon Progo Dome that situated on weakly undulated morphology with the elevation difference of 45 meters, the slope of 20.34%, and consisted of impermeable clastics sedimentary rocks. The Old Andesite Formation that is surrounding reflected that the steeply hills morphology with an elevation difference of 89.09 meters, the slope of 40.07%, and the permeable volcanic rocks. The research area is located in the eastern part of Kulon Progo Dome, included in Kulon Progo Regency. Springs are generally rising in between contact of Nanggulan Formation and Old Andesite Formation. These condition has become an interesting problem to study further. The purpose of this research is to understand the presence of springs. Whereas the aim of this research to determining morphology, lithology, and structural geology toward the presence of the springs. The research methods used by field observation and gravity measurement. The pattern of springs distribution not always follow in valley lineaments. The result of gravity measurement showed that the presence of springs around the Mujil traverse controlled by fault contact and stratigraphy contact. In contrast, of springs on the Sentolo traverse was controlled by stratigraphy contact. Springs controlled by fault, followed by valley lineament. The presence of springs due to stratigraphy contact occurred in contact with the permeable and impermeable rock. The presence of spring due to stratigraphy contact could use as a preliminary indication of the existence of contact of Nanggulan Formation and Old Andesite Formation.

Keywords: Springs, gravity, contact, stratigraphy, fault

1. INTRODUCTION

Old Andesite Formation that widespread in Kulon Progo Mountain consists of volcanic rocks [1]. In the Old Andesite Formation, Kebobutak Formation comprised of andesite breccia, tuff, lapilli tuff, agglomerates, and intercalation of lava [2]. The volcanism activity in Kulon Progo Mountain occurred in Late Oligocene–Middle Miocene [3]. Volcanism activity in Kulon Progo occurred in three stages with indicated the presence of three ancient volcanoes such as Gajah Mountain, Ijo Mountain, and Menoreh Mountain. Based on the total of lineaments, on Gajah Mountain, as the oldest volcano has 430 lineaments, Ijo Mountain has 345 lineaments, and Menoreh Mountain has 249 lineaments. Generally, the direction of lineaments is South East-North West [4]. By many lineaments caused the rocks to become more permeable.

Old Andesite Formation overlaid unconformity on Nanggulan Formation that well exposed in the eastern part of Kulon Progo Dome and contact to rock volcanic as a result of Gajah Mountain [4]. Nanggulan Formation consists of sandstone, shale with large and small foraminifera, and marl [5]. Based on rock variation, the Nanggulan Formation has more impermeable rock characteristics. The distribution of Nanggulan Formation placed on weakly undulated hills, whereas the Old Andesite Formation was on steep hills. On weakly undulated hills are used for urban settlements and agricultural land use. On the steep, undulated hills are used for farm, forest, and a few settlements. Contact of Nanggulan Formation and Old Andesite Formation is structural contact of thrust fault with the direction of North East-South West that caused the Nanggulan Formation was outcropped on the surface [4].

By the increase of clean water needs, some inhabitants used the springs to fulfill the daily need, due to the water from dug wells could not be enough. Generally, the springs emerge in between Nanggulan Formation and Old Andesite Formation. The objective of this research is to reveal the factors that caused the presence of springs in the research area. The purpose of this research is to

understand the presence of springs from the geological aspect. The aim of this research is also to determining morphology, lithology, and structural geology toward the presence of those springs.

2. GEOLOGY AND HYDROGEOLOGY OF THE KULON PROGO AREA

The Kulon Progo Mountain is an eastern part of South Serayu Mountain with the dome shape [1]. The morphology characterized by steep hills and its surroundings characterized by low hills. These morphological differences could cause by lithology difference.

Stratigraphy of the Kulon Progo comprised of some rock formations with the sort from oldest to youngest formation. Such as Nanggulan Formation, Old Andesite Formation, Jonggrangan Formation Sentolo Formation, and Quartenary unconsolidated sediments [1][2][6][7][8][9].

Nanggulan Formation has age in Middle Eocene to Oligocene [1][10][11][12][13], and Middle Eocene to Early Upper Eocene [14]. Nanggulan Formation divided into Kalisonggo members on the lower part and Seputih member on the upper part [5].

The result of age identification in volcanic rock with an isotope of 40K-40Ar showed that Old Andesite Formation formed from volcanism activity that occurred in Late Oligocene to Middle Eocene [3]. Old Andesite Formation divided into two groups, such as Kaligesing Formation and Dukuh Formation [5].

The Kaligesing Formation, which formed the moderate undulated morphology to steep undulation morphology, consists of monomic breccia with andesite fragment, sandstone, and lava. Dukuh Formation formed the weak to moderate undulated morphology was consisted of polymics breccia, andesite breccia, and sandstone. Based on morphology and rock association, the research area included in Dukuh Formation.

The geoelectrical study on Nanggulan Formation to the depth of 120 meters dominated by shale and tuffaceous sandstone with local distribution; by this case, the presence of aquifer in Nanggulan Formation is limited [15].

The lower part of the Jonggrangan Formation consists of calcareous tuff, Mollusca sandstone, shale with intercalation of lignite, and the upper part is consisted of bedded limestone, and coral limestone has aged in Early Miocene to Middle Miocene. It mapped on the center of Menoreh Mountain-Gajah-Ijo, formed as a conical hill [4]. In Jonggrangan Formation has springs that formed by lineaments or fractures. The distribution of springs and lineaments or fractures has the same direction as North East-South West [16]. Sentolo Formation is consisted of limestone and calcareous shale and has an interfingering relationship with Jonggrangan Formation [4].

The Wates groundwater basin divided into two groups, such as the Tersier Formation (Kebobutak Formation and Sentolo Formation) as the basement of The Wates groundwater basin and Quartenary Formation (alluvial and volcanic sediments of Young Merapi) as sediment filling of groundwater basin [17]. Generally, the recharge area in The Wates groundwater basin was on the elevation of 15 meters to 25 meters above sea level, located in the north part. In contrast, the discharge area was on the elevation of 15 meters to 0 meters above sea level, located in the south part [17].

3. THEORY

3.1 Spring

Groundwater is subsurface water located in the rock layer as an aquifer. Springs place for groundwater that emerged in the surface caused by the groundwater flows was cut by nature phenomenon until groundwater could emerge on the surface [18].

Based on hydraulic pressure in an aquifer, springs divided into two, such as artesian and gravity [19]. Artesian springs emerged caused by hydraulic pressure from the subsurface that could flow up at the same level as a piezometric surface without any pumping. The characteristic is sustainable due to the long distance of recharge and discharge. Gravitational springs emerge were not caused by pressure and horizontal flow direction.

The kind of these springs divided into three such as depression springs, contact gravity springs, and joint springs. Depression springs emerge due to groundwater-surface were cut by topography and included in shallow groundwater type. Contact gravity springs emerge due presence of contact between permeable and impermeable layer; also, the groundwater-surface cut by topography.

Contact of both layers occurred caused by stratigraphy or structural geology. Contact of springs generally occurred in an unconfined aquifer or shallow groundwater system. The turbulence groundwater is a spring caused by the presence of fractures on the permeable zone or joints on rugged rocks with low permeability. The groundwater generally formed when the groundwater flow cut by a break of slope.

3.2 Gravity

The gravity method usually used to determine for basement margin, distribution, thickness, and structural geology based on a variation of density. The physics law that likely to be essential for

gravity method development is Newton law [20], whereas the value of Bouguer anomaly obtained as an equation [21]:

$$\Delta \mathbf{gB} = \mathbf{gm} + (\Delta \mathbf{gFA} - \Delta \mathbf{gBP} + \Delta \mathbf{gT} + \Delta \mathbf{gtide}) - \Delta \mathbf{gn} \quad (1)$$

With ΔgB is Bouguer gravity anomaly, gm: the result of data observation, ΔgFA: gravity value of free air correction, ΔgBP: gravity value of Bouguer correction, ΔgT: gravity value of topography correction, Δgtide: gravity value of tidal correction and Δgn: gravity value of mathematics calculation.

The value of Simple Bouguer Anomaly correction (ΔgBA) is an addition of gravity value of observation data with elevation correction (gElev.) than diminished by theoretical gravity value (gϕ) [22], the density value average was set as 2.7 gr/cm^3 with correction factor about 0.1967 mgal/meter.

$$\Delta \mathbf{gBA} = \mathbf{gobs.} + \mathbf{gElev.} - \mathbf{g\phi} \quad (2)$$

The value of Quartenary aluvium gravity Bantul regency is 2.0-2.27 gr/cm^3, limestone gravity value is 2.5 gr/cm^3 and igneous rocks is 2.73-2.80 gr/cm^3 [23]. Kulon Progo area has a high gravity value about +50 to +145 mgal with the basement density value is about 2.8 gr/cm^3 that showed in depth of 3000 to 4000 meters, intrusion rock density is about 2.79 gr/cm^3 and sedimentary rock density is about 2.5 gr/cm^3 [24].

4. METHODS

In this research, the surface identification of the location and lithology of the spring. Morphometrical measurement, and subsurface identification with measured gravity value. The morphometric measurements, especially in valley lineaments, were conducted in Clumprit River, Klepu River, and Kalisonggo River, whereas on steep hills identified by Shuttle Radar Topography Mission image. The gravity measurements done in two traverses, such as Mujil dan Sentul traversed with measurements total of 47 points.

The research area located in the eastern part of Kulon Progo Dome. Administratively, it included in Nanggulan and Girimulyo Sub-District, Kulon Progo Regency, Yogyakarta Special Region (Fig. 1).

5. RESULT AND DISCUSSION

The morphological research area divided into two, such as steep hills and weakly undulated hills (Fig. 2). On steeply hills were characterized by angular morphology with the elevation differences of 89.09 meters and slope averages of 40.07%, also steeply river stream. This morphology consists of Old Andesite Formation. On the weakly undulated hills were characterized by elevation differences average of 45 meters and slope average of 20.34% also the wide and has meanders. On this morphology was consisted of Nanggulan Formation.

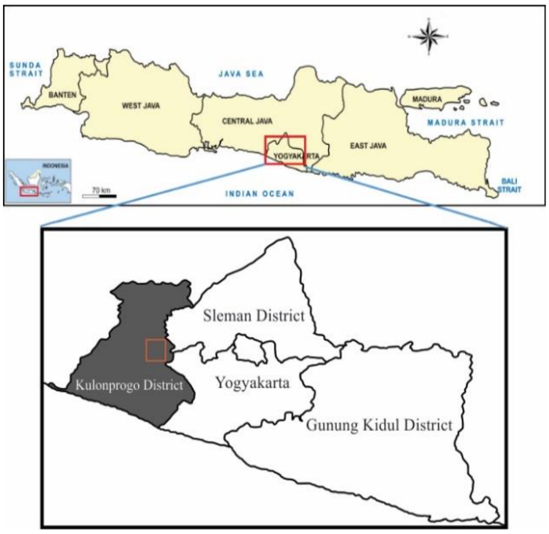

Fig. 1 Research area is in the administrative area of the Kulon Progo Regency.

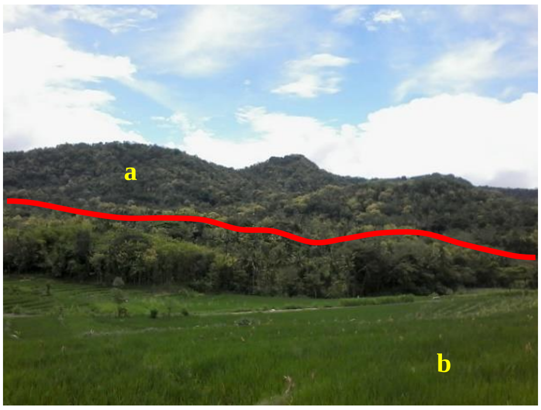

Fig. 2 Morphological research area a). Steeply hills, b). weakly undulated hills.

Nanggulan Formation consists of sandstone, quartz sandstone, intercalation of lignite, claystone, and calcareous claystone. The abundance of sandstone and claystone is more dominantly than other rocks. Generally, Nanggulan rock formation is impermeable. In the Old-Andesite Formation dominated by andesite breccia. On someplace was founded by the andesitic intrusion and andesitic lava. Those rock has many fractures, caused the rock to become permeable. Rock variation of Nanggulan Formation and Old Andesite Formation in Fig. 3.

In the research area, nine spring locations were identified from the largest at the north side to the

south side (Table 1). Springs generally founded at an elevation of 127 to 227 meters that emerged in between contact of andesite breccia and claystone.

One of the spring locations is in di Sentul Village (Fig. 4). Those springs emerge in permeable claystone and right on andesite breccia with many fractures. That breccia is more permeable.

Valley lineament is a character of the presence of a weak zone caused by tectonics that springs emerge followed the valley lineaments pattern. The result of valley lineament measurements (Fig. 5) determined that the distribution of springs is not followed by the valley lineaments pattern, even in some springs on the north side were not emerge on the valley.

If the distribution of the spring positioned on the geological map (Fig. 6), the springs would emerge in between contact of Nanggulan Formation and Old Andesite Formation. The subsurface geological condition depicted on the geological cross-section of A-A’ and B-B’ (Fig. 7 a & b).

Fig. 3a). Interbedded of sandstone and claystone in Nanggulan Formation, b). Fractures in Andesitic easily found more.

Fig. 4 Springs in Sentul Village emerge in between impermeable and permeable.

The gravity measurement in Mujil and Sentul traversed were data obtained in (Table 2). Gravity traverst（Fig. 8）was made to pass some springs locations, with the purpose of springs condition toward the local geological condition.

Table 1 Identification of springs location

No.	Location	Elevation (m)	Lithology
1	Sentul Village	183	Claystone
2	Kalisonggo Village	128	Claystone
3	Tempel Village	153	Andesite breccia
4	Kepek Village	215	Andesite breccia
5	Watumurah River	199	Andesite breccia
6	Klepu River	227	Andesite breccia
7	Kalisonggo River	132	Andesitic intrusion
8	Ngentak Village	127	Sandstone
9	Tileng Village	140	Andesite breccia

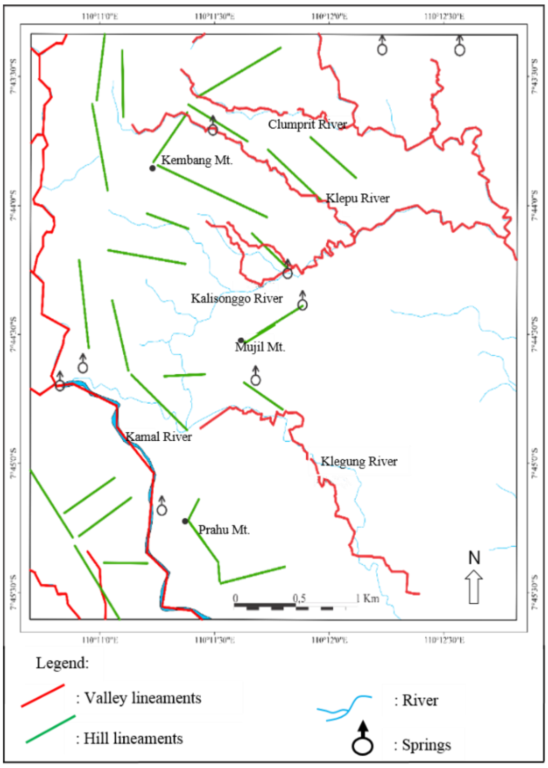

Fig. 5 The distribution pattern was not related to valley lineaments pattern.

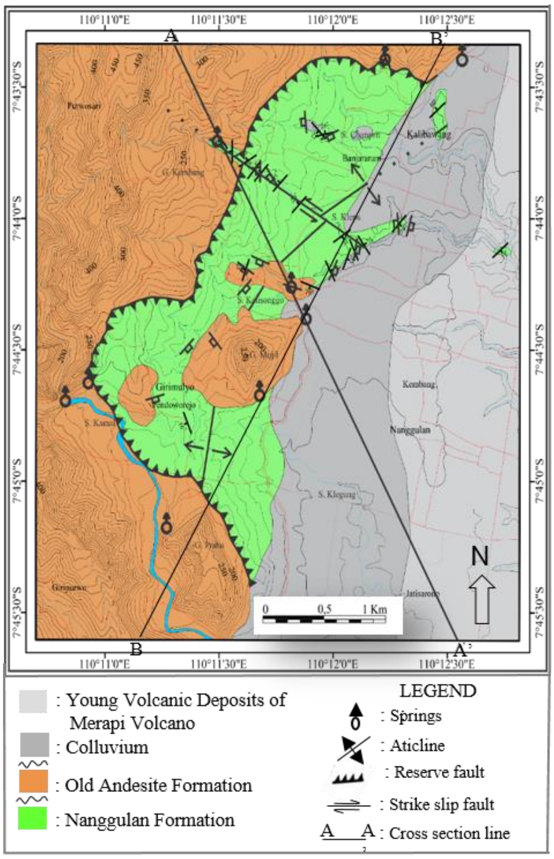

Fig. 6 The distribution of springs on the geological map.

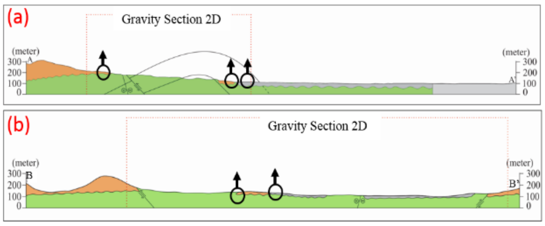

Fig. 7 The position of springs on geological cross-section (a) Mujil cross-section of A-A' and (b) Sentul cross-section of B-B'.

The result of gravity processing on Mujil traversed (Fig. 9) reflected that the presence of springs could cause by two factors such that one springs emerged in around the fault zone, and two springs emerged in contact of rock formation. Processing of gravity measurement on Sentul traverse (Fig. 10) depicted that two springs emerge in around the contact of rock formation.

Table 2 The result of gravity measurements.

Location	Time	Reading	Elevation (m)
Base	12:44:04	1866.44	139.17
G1	16:10:17	1821.35	159.74
G4	16:28:25	1824.85	173.24
G6	16:45:29	1824.70	151.33
G7	17:09:55	1827.27	140.96
G10	17:26:01	1830.84	126.07
Base	17:49:30	1828.85	139.17
Base	08:26:28	1828.79	139.17
G9	09:00:19	1829.90	129.49
G8	09:25:36	1826.03	145.02
G5	09:49:41	1821.85	162.77
G3	10:21:46	1820.62	164.87
G2	10:55:19	1812.59	198.74
G12	15:55:20	1832.07	144.11
G11	16:19:34	1832.98	139.57
Base	19:14:30	1833.26	139.17
Base	08:21:06	1833.27	139.17
G47	12:33:31	1809.60	241.80
Base	17:33:34	1833.31	139.17
Base	08:43:20	1833.18	139.17
G14	09:38:00	1833.04	139.39
G15	09:13:40	1833.92	135.11
G13	10:05:20	1831.22	147.99
G16	10:30:00	1832.57	143.87
G44	14:13:00	1814.57	223.10
G45	14:42:00	1810.45	238.45
G46	15:33:00	1805.70	261.19
G43	16:06:40	1809.65	246.27
G42	16:34:20	1814.13	226.73
G41	16:57:40	1818.58	207.52
Base	17:58:00	1833.20	139.17
Base	08:31:03	1832.81	139.17
G18	09:09:41	1834.10	143.04
G21	09:33:28	1834.82	142.03
G20	09:59:59	1834.15	145.16
G36	10:25:42	1830.90	158.23
G37	10:49:20	1829.90	164.06
G38	11:12:57	1823.19	191.30
G39	11:35:56	1819.55	206.68
G40	13:45:51	1827.19	169.85
G19	14:45:54	1833.73	142.58
G17	15:05:56	1833.03	144.38
Base	16:35:52	1832.72	139.17
Base	07:45:17	1832.80	139.17
G35	09:21:00	1832.90	151.13
G23	13:27:13	1829.34	167.34
G24	14:01:20	1820.05	210.69
G28	14:28:34	1826.08	183.64
G27	15:01:01	1833.50	154.55
G26	15:25:48	1833.61	152.81
G25	15:49:44	1834.52	146.96
G22	16:18:00	1835.51	140.26
Base	16:53:22	1832.81	139.17
Base	10:27:35	1824.52	139.17
G34	14:18:52	1814.40	207.10
Base	17:16:33	1824.58	139.17
Base	08:04:45	1824.35	139.17
G33	09:20:48	1820.40	181.38
G30	13:58:00	1827.34	147.16
G29	14:20:31	1820.86	173.66
G32	16:44:09	1821.67	173.90
G31	17:06:55	1824.52	160.78
Base	17:51:35	1824.38	139.17

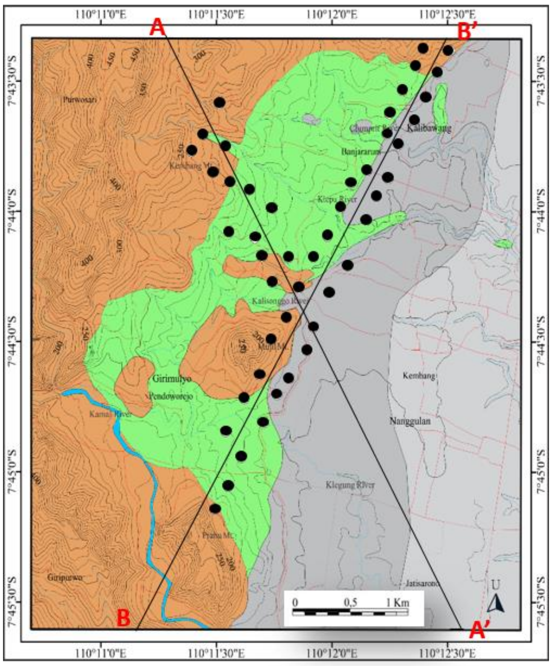

Fig. 8 The gravity measurement by the point.

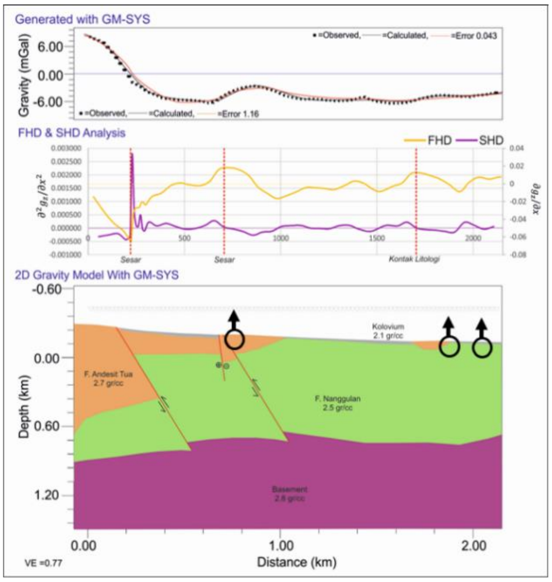

Fig. 9 Mujil traversed gravity cross-section (A-A').

6. CONCLUSION

The springs distribution does not always follow by valley lineaments pattern. In some places, the presence of springs not followed by the presence of the valley. The distribution of springs that reflected on the geological map followed the pattern of contact of Nanggulan Formation and Old Andesite Formation. Nanggulan Formation is consisted of impermeable rocks, whereas the Old Andesite Formation has consisted of permeable rocks.

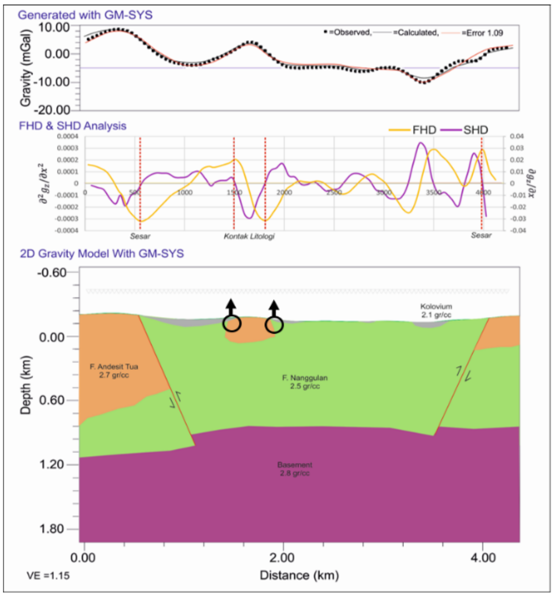

Fig. 10 Gravity cross-section on Sentul traversed (B-B').

A thrust fault identified gravity data measurement on Mujil traverse. Those faults caused the springs formed. On the other side, in the eastern part of the research area, the springs emerge controlled by stratigraphy contact. On Sentul traverse, the stratigraphy contact could be the central control in the presence of springs. This condition gives evidence that the presence of springs could control by structural geology and stratigraphy contact. Springs that emerge caused by structural would follow by valley lineaments pattern. Springs that emerge due to stratigraphy contact in between impermeable rocks (Nanggulan Formation) and permeable rocks (Old Andesite Formation) could indicate that the presence of springs would found on the margin of both formations.

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THE SPRINGS PHENOMENA AS CONTACTS BOLDER MARKER BETWEEN NANGGULAN AND OLD ANDESITE FORMATIONS AT THE EASTERN PART OF KULON PROGO DOME, INDONESIA

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ABSTRACT: Nanggulan Formation located in the eastern part of Kulon Progo Dome that situated on weakly undulated morphology with the elevation difference of 45 meters, the slope of 20.34%, and consisted of impermeable clastics sedimentary rocks. The Old Andesite Formation that is surrounding reflected that the steeply hills morphology with an elevation difference of 89.09 meters, the slope of 40.07%, and the permeable volcanic rocks. The research area is located in the eastern part of Kulon Progo Dome, included in Kulon Progo Regency. Springs are generally rising in between contact of Nanggulan Formation and Old Andesite Formation. These condition has become an interesting problem to study further. The purpose of this research is to understand the presence of springs. Whereas the aim of this research to determining morphology, lithology, and structural geology toward the presence of the springs. The research methods used by field observation and gravity measurement. The pattern of springs distribution not always follow in valley lineaments. The result of gravity measurement showed that the presence of springs around the Mujil traverse controlled by fault contact and stratigraphy contact. In contrast, of springs on the Sentolo traverse was controlled by stratigraphy contact. Springs controlled by fault, followed by valley lineament. The presence of springs due to stratigraphy contact occurred in contact with the permeable and impermeable rock. The presence of spring due to stratigraphy contact could use as a preliminary indication of the existence of contact of Nanggulan Formation and Old Andesite Formation.

Keywords: Springs, gravity, contact, stratigraphy, fault

1. INTRODUCTION

Old Andesite Formation that widespread in Kulon Progo Mountain consists of volcanic rocks [1]. In the Old Andesite Formation, Kebobutak Formation comprised of andesite breccia, tuff, lapilli tuff, agglomerates, and intercalation of lava [2]. The volcanism activity in Kulon Progo Mountain occurred in Late Oligocene–Middle Miocene [3]. Volcanism activity in Kulon Progo occurred in three stages with indicated the presence of three ancient volcanoes such as Gajah Mountain, Ijo Mountain, and Menoreh Mountain. Based on the total of lineaments, on Gajah Mountain, as the oldest volcano has 430 lineaments, Ijo Mountain has 345 lineaments, and Menoreh Mountain has 249 lineaments. Generally, the direction of lineaments is South East-North West [4]. By many lineaments caused the rocks to become more permeable.

Old Andesite Formation overlaid unconformity on Nanggulan Formation that well exposed in the eastern part of Kulon Progo Dome and contact to rock volcanic as a result of Gajah Mountain [4]. Nanggulan Formation consists of sandstone, shale with large and small foraminifera, and marl [5]. Based on rock variation, the Nanggulan Formation has more impermeable rock characteristics. The distribution of Nanggulan Formation placed on weakly undulated hills, whereas the Old Andesite Formation was on steep hills. On weakly undulated hills are used for urban settlements and agricultural land use. On the steep, undulated hills are used for farm, forest, and a few settlements. Contact of Nanggulan Formation and Old Andesite Formation is structural contact of thrust fault with the direction of North East-South West that caused the Nanggulan Formation was outcropped on the surface [4].

By the increase of clean water needs, some inhabitants used the springs to fulfill the daily need, due to the water from dug wells could not be enough. Generally, the springs emerge in between Nanggulan Formation and Old Andesite Formation. The objective of this research is to reveal the factors that caused the presence of springs in the research area. The purpose of this research is to

understand the presence of springs from the geological aspect. The aim of this research is also to determining morphology, lithology, and structural geology toward the presence of those springs.

2. GEOLOGY AND HYDROGEOLOGY OF THE KULON PROGO AREA

The Kulon Progo Mountain is an eastern part of South Serayu Mountain with the dome shape [1]. The morphology characterized by steep hills and its surroundings characterized by low hills. These morphological differences could cause by lithology difference.

Stratigraphy of the Kulon Progo comprised of some rock formations with the sort from oldest to youngest formation. Such as Nanggulan Formation, Old Andesite Formation, Jonggrangan Formation Sentolo Formation, and Quartenary unconsolidated sediments [1][2][6][7][8][9].

Nanggulan Formation has age in Middle Eocene to Oligocene [1][10][11][12][13], and Middle Eocene to Early Upper Eocene [14]. Nanggulan Formation divided into Kalisonggo members on the lower part and Seputih member on the upper part [5].

The result of age identification in volcanic rock with an isotope of 40K-40Ar showed that Old Andesite Formation formed from volcanism activity that occurred in Late Oligocene to Middle Eocene [3]. Old Andesite Formation divided into two groups, such as Kaligesing Formation and Dukuh Formation [5].

The Kaligesing Formation, which formed the moderate undulated morphology to steep undulation morphology, consists of monomic breccia with andesite fragment, sandstone, and lava. Dukuh Formation formed the weak to moderate undulated morphology was consisted of polymics breccia, andesite breccia, and sandstone. Based on morphology and rock association, the research area included in Dukuh Formation.

The geoelectrical study on Nanggulan Formation to the depth of 120 meters dominated by shale and tuffaceous sandstone with local distribution; by this case, the presence of aquifer in Nanggulan Formation is limited [15].

The lower part of the Jonggrangan Formation consists of calcareous tuff, Mollusca sandstone, shale with intercalation of lignite, and the upper part is consisted of bedded limestone, and coral limestone has aged in Early Miocene to Middle Miocene. It mapped on the center of Menoreh Mountain-Gajah-Ijo, formed as a conical hill [4]. In Jonggrangan Formation has springs that formed by lineaments or fractures. The distribution of springs and lineaments or fractures has the same direction as North East-South West [16]. Sentolo Formation is consisted of limestone and calcareous shale and has an interfingering relationship with Jonggrangan Formation [4].

The Wates groundwater basin divided into two groups, such as the Tersier Formation (Kebobutak Formation and Sentolo Formation) as the basement of The Wates groundwater basin and Quartenary Formation (alluvial and volcanic sediments of Young Merapi) as sediment filling of groundwater basin [17]. Generally, the recharge area in The Wates groundwater basin was on the elevation of 15 meters to 25 meters above sea level, located in the north part. In contrast, the discharge area was on the elevation of 15 meters to 0 meters above sea level, located in the south part [17].

3. THEORY

3.1 Spring

Groundwater is subsurface water located in the rock layer as an aquifer. Springs place for groundwater that emerged in the surface caused by the groundwater flows was cut by nature phenomenon until groundwater could emerge on the surface [18].

Based on hydraulic pressure in an aquifer, springs divided into two, such as artesian and gravity [19]. Artesian springs emerged caused by hydraulic pressure from the subsurface that could flow up at the same level as a piezometric surface without any pumping. The characteristic is sustainable due to the long distance of recharge and discharge. Gravitational springs emerge were not caused by pressure and horizontal flow direction.

The kind of these springs divided into three such as depression springs, contact gravity springs, and joint springs. Depression springs emerge due to groundwater-surface were cut by topography and included in shallow groundwater type. Contact gravity springs emerge due presence of contact between permeable and impermeable layer; also, the groundwater-surface cut by topography.

Contact of both layers occurred caused by stratigraphy or structural geology. Contact of springs generally occurred in an unconfined aquifer or shallow groundwater system. The turbulence groundwater is a spring caused by the presence of fractures on the permeable zone or joints on rugged rocks with low permeability. The groundwater generally formed when the groundwater flow cut by a break of slope.

3.2 Gravity

The gravity method usually used to determine for basement margin, distribution, thickness, and structural geology based on a variation of density. The physics law that likely to be essential for

gravity method development is Newton law [20], whereas the value of Bouguer anomaly obtained as an equation [21]:

$$\Delta gB = gm + (\Delta gFA - \Delta gBP + \Delta gT + \Delta gtide) - \Delta gn \quad (1)$$

With ΔgB is Bouguer gravity anomaly, gm: the result of data observation, ΔgFA: gravity value of free air correction, ΔgBP: gravity value of Bouguer correction, ΔgT: gravity value of topography correction, Δgtide: gravity value of tidal correction and Δgn: gravity value of mathematics calculation.

The value of Simple Bouguer Anomaly correction (ΔgBA) is an addition of gravity value of observation data with elevation correction (gElev.) than diminished by theoretical gravity value (gϕ) [22], the density value average was set as 2.7 gr/cm^3 with correction factor about 0.1967 mgal/meter.

$$\Delta gBA = gobs. + gElev. - g\phi \quad (2)$$

The value of Quartenary aluvium gravity Bantul regency is 2.0-2.27 gr/cm^3, limestone gravity value is 2.5 gr/cm^3 and igneous rocks is 2.73-2.80 gr/cm^3 [23]. Kulon Progo area has a high gravity value about +50 to +145 mgal with the basement density value is about 2.8 gr/cm^3 that showed in depth of 3000 to 4000 meters, intrusion rock density is about 2.79 gr/cm^3 and sedimentary rock density is about 2.5 gr/cm^3 [24].

4. METHODS

In this research, the surface identification of the location and lithology of the spring. Morphometrical measurement, and subsurface identification with measured gravity value. The morphometric measurements, especially in valley lineaments, were conducted in Clumprit River, Klepu River, and Kalisonggo River, whereas on steep hills identified by Shuttle Radar Topography Mission image. The gravity measurements done in two traverses, such as Mujil dan Sentul traversed with measurements total of 47 points.

The research area located in the eastern part of Kulon Progo Dome. Administratively, it included in Nanggulan and Girimulyo Sub-District, Kulon Progo Regency, Yogyakarta Special Region (Fig. 1).

5. RESULT AND DISCUSSION

The morphological research area divided into two, such as steep hills and weakly undulated hills (Fig. 2). On steeply hills were characterized by angular morphology with the elevation differences of 89.09 meters and slope averages of 40.07%, also steeply river stream. This morphology consists of Old Andesite Formation. On the weakly undulated hills were characterized by elevation differences average of 45 meters and slope average of 20.34% also the wide and has meanders. On this morphology was consisted of Nanggulan Formation.

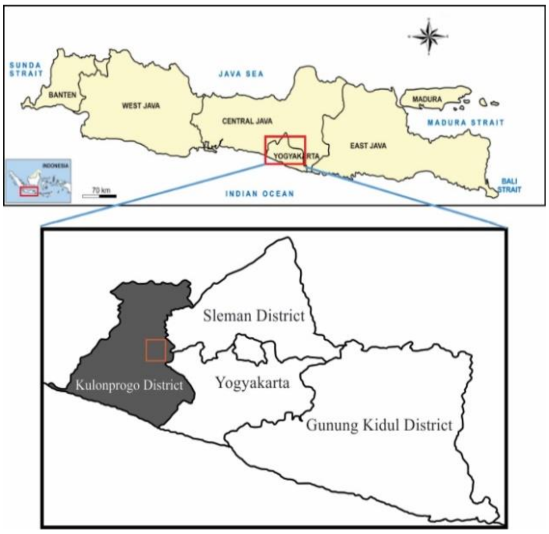

Fig. 1 Research area is in the administrative area of the Kulon Progo Regency.

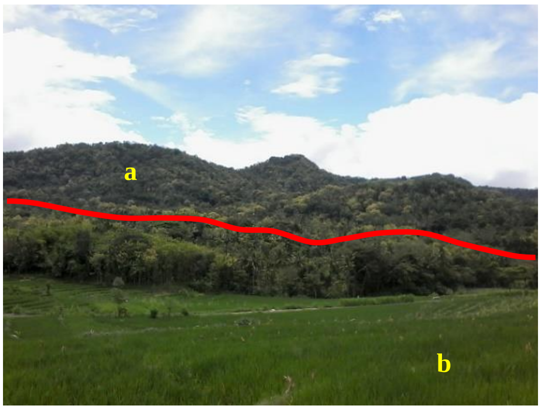

Fig. 2 Morphological research area a). Steeply hills, b). weakly undulated hills.

Nanggulan Formation consists of sandstone, quartz sandstone, intercalation of lignite, claystone, and calcareous claystone. The abundance of sandstone and claystone is more dominantly than other rocks. Generally, Nanggulan rock formation is impermeable. In the Old-Andesite Formation dominated by andesite breccia. On someplace was founded by the andesitic intrusion and andesitic lava. Those rock has many fractures, caused the rock to become permeable. Rock variation of Nanggulan Formation and Old Andesite Formation in Fig. 3.

In the research area, nine spring locations were identified from the largest at the north side to the

south side (Table 1). Springs generally founded at an elevation of 127 to 227 meters that emerged in between contact of andesite breccia and claystone.

One of the spring locations is in di Sentul Village (Fig. 4). Those springs emerge in permeable claystone and right on andesite breccia with many fractures. That breccia is more permeable.

Valley lineament is a character of the presence of a weak zone caused by tectonics that springs emerge followed the valley lineaments pattern. The result of valley lineament measurements (Fig. 5) determined that the distribution of springs is not followed by the valley lineaments pattern, even in some springs on the north side were not emerge on the valley.

If the distribution of the spring positioned on the geological map (Fig. 6), the springs would emerge in between contact of Nanggulan Formation and Old Andesite Formation. The subsurface geological condition depicted on the geological cross-section of A-A’ and B-B’ (Fig. 7 a & b).

Fig. 3a). Interbedded of sandstone and claystone in Nanggulan Formation, b). Fractures in Andesitic easily found more.

Fig. 4 Springs in Sentul Village emerge in between impermeable and permeable.

The gravity measurement in Mujil and Sentul traversed were data obtained in (Table 2). Gravity traverst（Fig. 8）was made to pass some springs locations, with the purpose of springs condition toward the local geological condition.

Table 1 Identification of springs location

No.	Location	Elevation (m)	Lithology
1	Sentul Village	183	Claystone
2	Kalisonggo Village	128	Claystone
3	Tempel Village	153	Andesite breccia
4	Kepek Village	215	Andesite breccia
5	Watumurah River	199	Andesite breccia
6	Klepu River	227	Andesite breccia
7	Kalisonggo River	132	Andesitic intrusion
8	Ngentak Village	127	Sandstone
9	Tileng Village	140	Andesite breccia

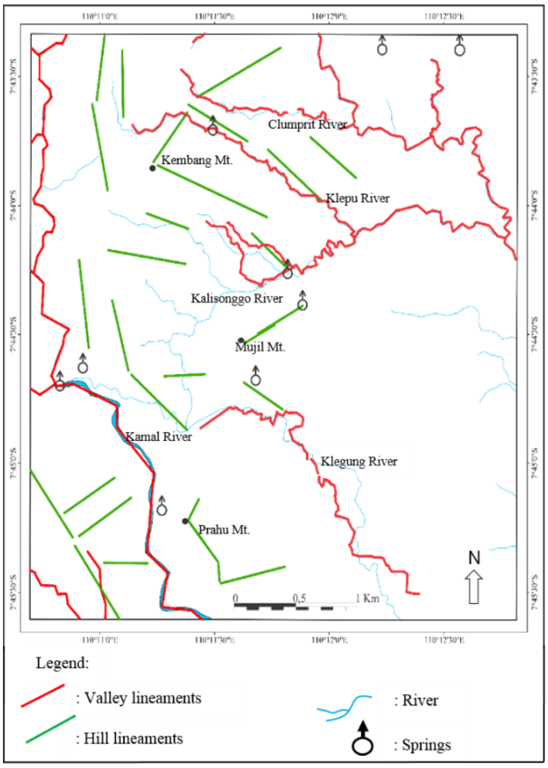

Fig. 5 The distribution pattern was not related to valley lineaments pattern.

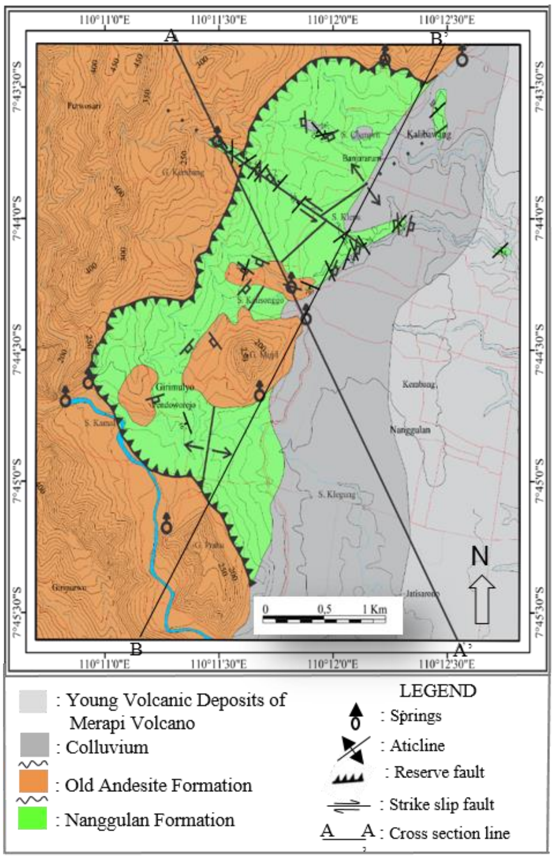

Fig. 6 The distribution of springs on the geological map.

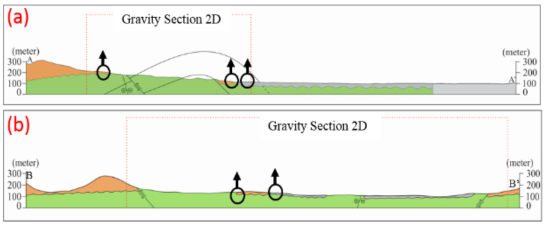

Fig. 7 The position of springs on geological cross-section (a) Mujil cross-section of A-A' and (b) Sentul cross-section of B-B'.

The result of gravity processing on Mujil traversed (Fig. 9) reflected that the presence of springs could cause by two factors such that one springs emerged in around the fault zone, and two springs emerged in contact of rock formation. Processing of gravity measurement on Sentul traverse (Fig. 10) depicted that two springs emerge in around the contact of rock formation.

Table 2 The result of gravity measurements.

Location	Time	Reading	Elevation (m)
Base	12:44:04	1866.44	139.17
G1	16:10:17	1821.35	159.74
G4	16:28:25	1824.85	173.24
G6	16:45:29	1824.70	151.33
G7	17:09:55	1827.27	140.96
G10	17:26:01	1830.84	126.07
Base	17:49:30	1828.85	139.17
Base	08:26:28	1828.79	139.17
G9	09:00:19	1829.90	129.49
G8	09:25:36	1826.03	145.02
G5	09:49:41	1821.85	162.77
G3	10:21:46	1820.62	164.87
G2	10:55:19	1812.59	198.74
G12	15:55:20	1832.07	144.11
G11	16:19:34	1832.98	139.57
Base	19:14:30	1833.26	139.17
Base	08:21:06	1833.27	139.17
G47	12:33:31	1809.60	241.80
Base	17:33:34	1833.31	139.17
Base	08:43:20	1833.18	139.17
G14	09:38:00	1833.04	139.39
G15	09:13:40	1833.92	135.11
G13	10:05:20	1831.22	147.99
G16	10:30:00	1832.57	143.87
G44	14:13:00	1814.57	223.10
G45	14:42:00	1810.45	238.45
G46	15:33:00	1805.70	261.19
G43	16:06:40	1809.65	246.27
G42	16:34:20	1814.13	226.73
G41	16:57:40	1818.58	207.52
Base	17:58:00	1833.20	139.17
Base	08:31:03	1832.81	139.17
G18	09:09:41	1834.10	143.04
G21	09:33:28	1834.82	142.03
G20	09:59:59	1834.15	145.16
G36	10:25:42	1830.90	158.23
G37	10:49:20	1829.90	164.06
G38	11:12:57	1823.19	191.30
G39	11:35:56	1819.55	206.68
G40	13:45:51	1827.19	169.85
G19	14:45:54	1833.73	142.58
G17	15:05:56	1833.03	144.38
Base	16:35:52	1832.72	139.17
Base	07:45:17	1832.80	139.17
G35	09:21:00	1832.90	151.13
G23	13:27:13	1829.34	167.34
G24	14:01:20	1820.05	210.69
G28	14:28:34	1826.08	183.64
G27	15:01:01	1833.50	154.55
G26	15:25:48	1833.61	152.81
G25	15:49:44	1834.52	146.96
G22	16:18:00	1835.51	140.26
Base	16:53:22	1832.81	139.17
Base	10:27:35	1824.52	139.17
G34	14:18:52	1814.40	207.10
Base	17:16:33	1824.58	139.17
Base	08:04:45	1824.35	139.17
G33	09:20:48	1820.40	181.38
G30	13:58:00	1827.34	147.16
G29	14:20:31	1820.86	173.66
G32	16:44:09	1821.67	173.90
G31	17:06:55	1824.52	160.78
Base	17:51:35	1824.38	139.17

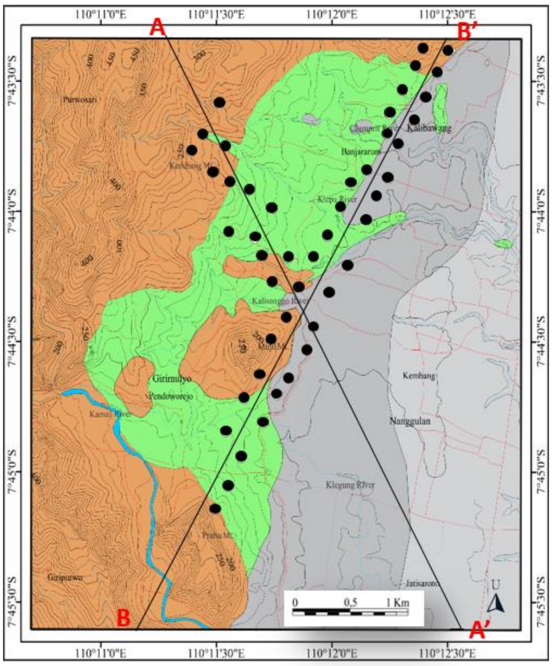

Fig. 8 The gravity measurement by the point.

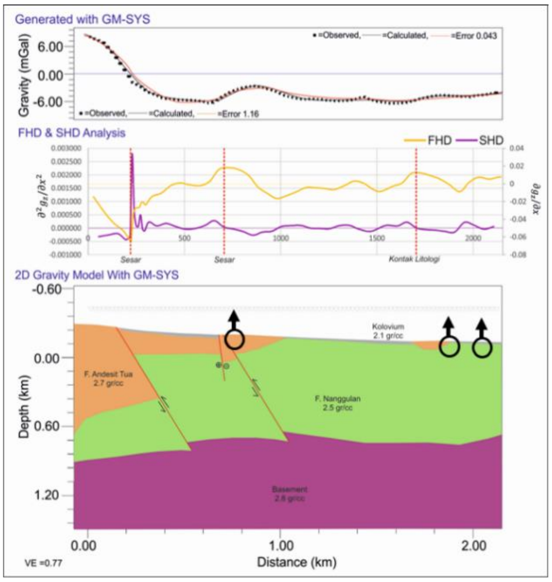

Fig. 9 Mujil traversed gravity cross-section (A-A').

6. CONCLUSION

The springs distribution does not always follow by valley lineaments pattern. In some places, the presence of springs not followed by the presence of the valley. The distribution of springs that reflected on the geological map followed the pattern of contact of Nanggulan Formation and Old Andesite Formation. Nanggulan Formation is consisted of impermeable rocks, whereas the Old Andesite Formation has consisted of permeable rocks.

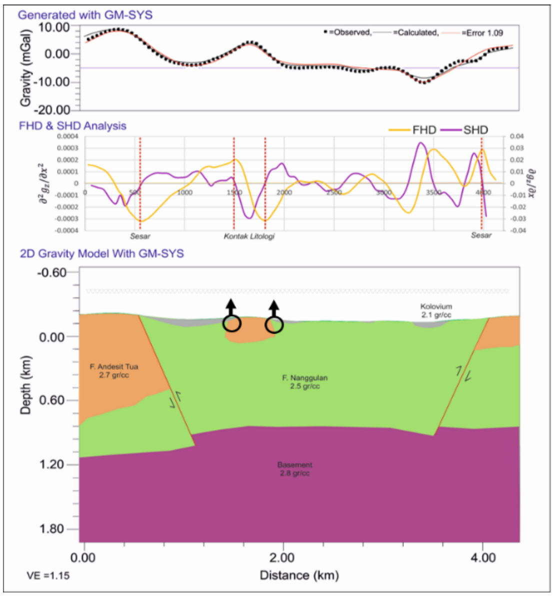

Fig. 10 Gravity cross-section on Sentul traversed (B-B').

A thrust fault identified gravity data measurement on Mujil traverse. Those faults caused the springs formed. On the other side, in the eastern part of the research area, the springs emerge controlled by stratigraphy contact. On Sentul traverse, the stratigraphy contact could be the central control in the presence of springs. This condition gives evidence that the presence of springs could control by structural geology and stratigraphy contact. Springs that emerge caused by structural would follow by valley lineaments pattern. Springs that emerge due to stratigraphy contact in between impermeable rocks (Nanggulan Formation) and permeable rocks (Old Andesite Formation) could indicate that the presence of springs would found on the margin of both formations.

7. ACKNOWLEDGMENTS

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