

The Volcanostratigraphy of the Geothermal Area of Mount Ungaran, Central Java

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Abstract. The Ungaran Geothermal Working Area (WKP) is located in Central Java, Indonesia, and is associated with the ancient composite volcano, Mount Ungaran. This study focuses on the volcanostratigraphy of the Mount Ungaran geothermal area, which is part of the Ungaran Brigade system linked to the formation of the Ungaran Caldera. The geothermal system is believed to be connected to geological processes from the Pre-Caldera Ungaran period through to the Post-Caldera Ungaran period. The Bregada Ungaran is composed of older formations (Khuluk Ungaran Tua) such as Kaligesik Hummock and Tungku Hummock, and younger formations (Young Ungaran Crown) including Pengion Hummock, Songo Hummock, and Godong Hummock. The study utilizes remote sensing data, specifically ASTER DEM, to create a digital elevation model and identify volcanostratigraphic units. The volcanostratigraphic method is used using the source of the eruption center that can still be identified, for example, the existence of circular features and the morphological shape of the volcanic cone that is clear in satellite images. The sources of the eruption centers that can be identified are closely related to the relatively young age, generally in the Quaternary Period. On the regional scale of the Mount Ungaran WKP with a scale map of 1 : 100.000, three Brigades were identified around the Mount Ungaran WKP, namely Sumbing Brigade which is on the southwest side consisting of Sumbing Crown and Sindoro Crown. Based on the 1 : 50.000 scale map on the Ungaran WKP, it was identified into 2 Crown (Main Eruption Center), namely Young Ungaran Crown (Kh. Ung. Muda) and Old Ungaran Crown (Kh.Ung.Tua) on the scale map of 1 : 50.000 identified 5 volcanostratigraphic units as Hummock originating from the central eruption and eruptions including Pengion Hummock (Gm. Pgn), Songo Hummock (Gm.Sgo), Godong Hummock (Gm. Gdg), Tungku Hummock (Gm. Tgk) and Kaligesik Hummock (Gm. kgk).

Keywords: *Ungaran, Vulkanostratigrafi, Gunung Api Purba, Geologi.*

1 Introduction

The Ungaran Geothermal Working Area (WKP) is located on the island of Java and is administratively located in Central Java Province. The Mount Ungaran

WKP area is located 40 km southwest of Semarang Regency, Central Java Province. Mount Ungaran WKP is one of the ancient volcanoes with a composite type.

Composite volcanoes, including compound volcanoes, are large volcanic structures that undergo a long process of formation from lava as well as volcanic materials such as pyroclastic produced from one or more eruptions. This type of volcano is commonly found at the boundary of convergent plates and is often associated with andesite volcanoes in high mountainous areas. The landscape of composite volcanoes varies depending on age, eruption history, and degree of erosion, including possible sector collapse to the formation of the caldera. To understand the volcanostratigraphic boundaries of the Mount Ungaran WKP which can be the basis for determining the boundaries of the geothermal system. The method of dividing volcanic stratigraphic units uses the principle of volcanostratigraphy based on the Indonesian Stratigraphy Code (SSI) from Martodjojo and Djuhaeni (1996).

The division of volcanic stratigraphic units (from small to large) refers to the Indonesian Stratigraphic Code (SSI) from Martodjojo and Djuhaeni (1996) divided into the smallest eruption center (Hummock), single volcanic cone (khuluk), volcanic cone group (Brigade), caldera group or large-scale volcanic cone group (manggala), to volcanic complexes formed from the same tectonic system (arc).

At the geothermal exploration stage, it is important to determine the boundaries of volcanic rocks by the interpretation of remote sensing data. In this study, ASTER DEM data is used to create a digital elevation model. This data will be used to create a volcanostratigraphic unit with an explanation of the ridges and rivers that will point to the center of the eruption. One cone will form one volcanostratigraphic unit. The boundaries of the units then close each other with other eruption products or other rocks and then with the presence of cracks there is a thermal manifestation so that it is present in the form of hot springs and cold springs whose chemical content is influenced by thermal fluids.

2 Geology Setting

The geological history of Java Island is a complex arrangement of basin formations, faults, folds, and volcanism under the influence of different pressure regimes from time to time. The tectonic evolution of Java Island produces a geological structure with an orderly pattern. In general, there are three directions of structural patterns in general, namely the Northeast-Southwest (NE-SW) direction called the Meratus pattern, the North-South (NS) or Sunda direction, and the East-West direction (EW) which is called the Java pattern pattern. The

change in the *crataceous subduction path* that crosses the Northeast-Southwest (NE-SW) and then in the relative East-West (BT) direction since the Oligocene until now has resulted in a very complex tertiary geological arrangement on the island of Java.

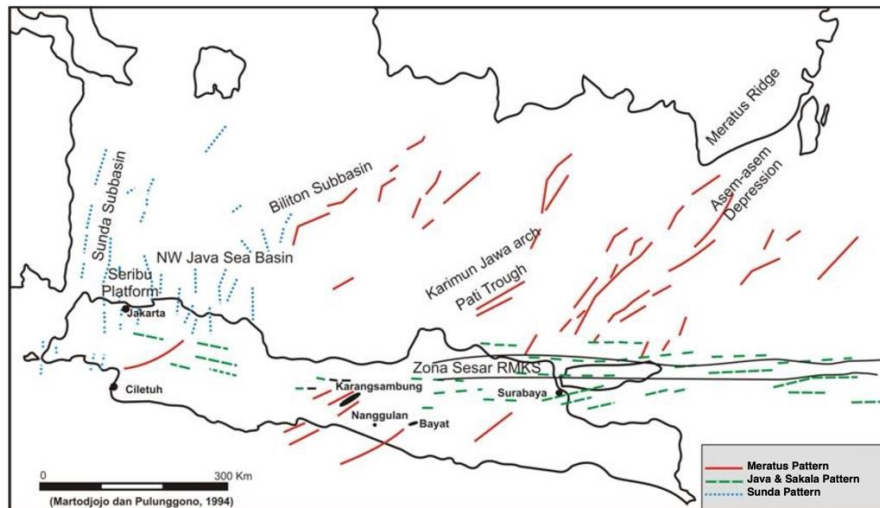


Figure 1. Trends in the Structure of Java Region (Pulunggono & Martodjojo, 1994)

Java Island is in the subduction zone, a collision between the Indo-Australian Plate and the Eurasian Plate. The history of Javanese subduction is also the history of magmatism paths that have formed over time, forming a pattern of magmatism that is rich in igneous and volcanic rock formations.

Soeria-Atmadja et al., 1994 divided Javanese magmatism into four belts of volcanism (Figure 2) as follows:

1. The Eocene to Middle Miocene volcanic belt, which is manifested as the Southern Mountains Zone;
2. The Upper Miocene to Pliocene volcanic belt, located north of the Mountain from the Mountain's southern line. In the form of lava intrusion and igneous rocks;
3. The Quaternary volcanic arc belt, consisting of a series of active volcanoes;
4. Back arc of the quaternary volcanic belt, Muria and Lasem.

The rocks of Pre-Tertiary magmatism on the island of Java are only exposed in Ciletuh, Karang Sambung, and Bayat. In these places, the rocks found are generally igneous and metamorphic rocks. Meanwhile, rocks that show magmatism activity consist of oceanic crustal rocks such as peridotite, gabbro, diabas, basalt. This rock has partly become a metamorphic rock.

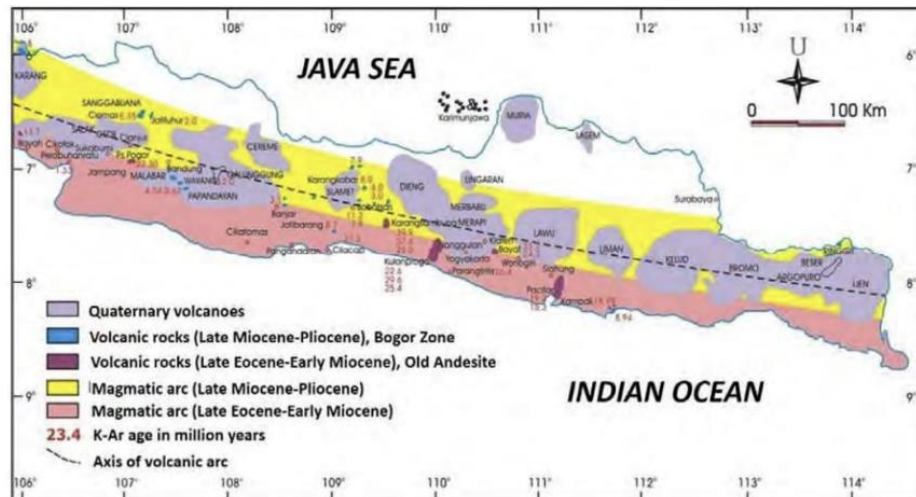


Figure 2. Paleogene Distribution – Quaternary Volcanoes in Java (Soeria Atmadja et al., 1991)

Magmatism activity during the Eocene period is shown by the existence of the Jatibarang Formation in northern West Java, the basaltic embankment that cuts the Coral Connection Formation in the North Kebumen area, Eocene rocks in Bayat, and basaltic pillow lava in Grindulu Pacitan. River. The Jatibarang Formation is a volcanic rock that can be found in every drilling well. The thickness of the Jatibarang Formation is approximately 1,200 meters.

The island of Java is formed by a series of volcanoes of the Middle Oligocene and Pliocene-Quaternary ages. The constituent rocks consist of volcanic rocks in the form of pyroclastic breccia, lahari breccia, lava, tufa volcanic sandstone that settles on land. and the marine environment. The formation of the volcanic belt is closely related to the subduction of the Indian Ocean plate at the end of the Paleogene.

Mount Ungaran is a magmatism zone near the back arc located in the city of Mount Ungaran, Central Java with an altitude of approximately 2050 meters above sea level. Geologically, Mount Ungaran is located in rocks that are associated with tertiary rock formations in the North Serayu Basin to the west and the Kendeng Basin to the northeast. Mount Ungaran is a series of northernmost

volcanic straightness, Mount Merapi-Mount Merbabu-Mount Ungaran, this phenomenon is suspected to be related to the existence of a large fault that runs north-south.

The geological structure in the Mount Ungaran area is controlled by a collapse structure that extends from west to southeast of Mount Ungaran. Pre-caldera volcanic rocks are controlled by northwest-southwest and southeast-southwest fault systems, and in post-caldera volcanic rocks there are few structures where they are controlled by regional fault systems (Budiardjo & Budihardi, 1997a).

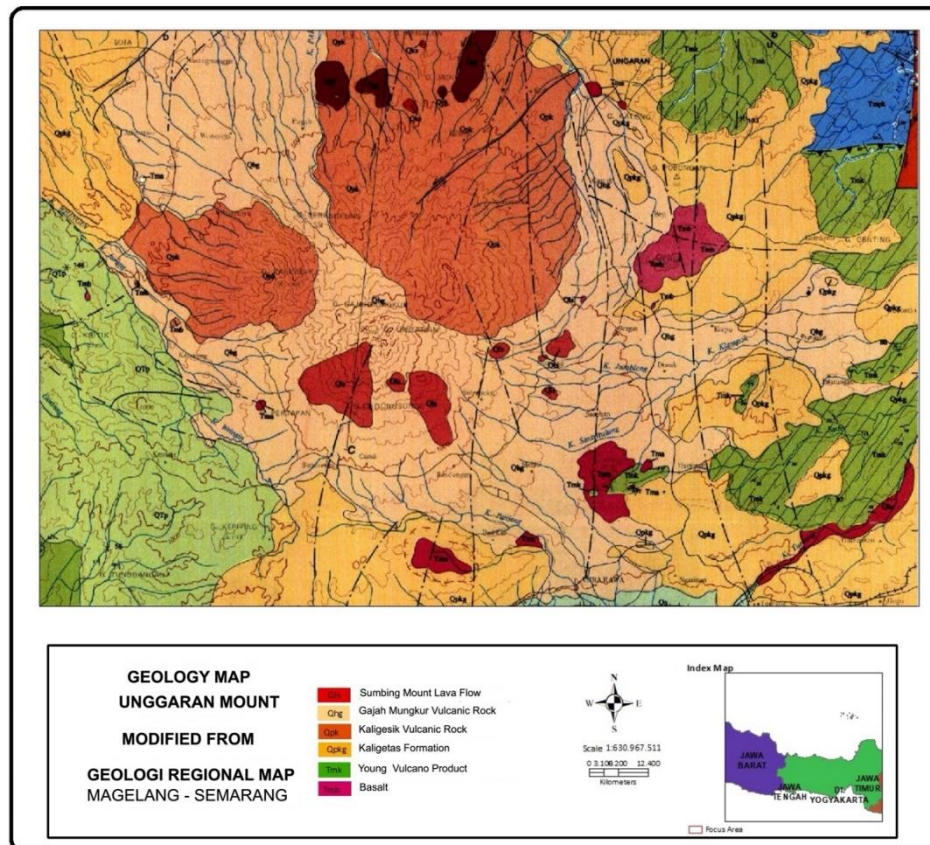


Figure 3. Regional Geological Map of Mount Ungaran (Thanden et al., 1996),

Mount Ungaran has a varied rock composition, consisting of basalt containing olivine, pyroxene andesite, hornblende andesite and also gabbro. Mount Ungaran underwent two developments, initially producing andesite basalt type volcanic rocks during the Lower Pleistocene. Later developments in the Middle Pleistocene period changed to tend to andesite rocks and then collapse. The second growth began again during the Upper Pleistocene and Holocene, resulting

in the occurrence of the second and third Ungaran Mountains. In its development, Mount Ungaran experienced tectonic collapse caused by gravitational changes due to weak bedrock.

Mount Ungaran from regional geology (Thanden et al., 1996), consists mostly of igneous rocks or volcanic eruptions and sedimentary rocks, the oldest of which is Middle Miocene (11.8 – 16 million years old) and the youngest is Quaternary (less than 1.8 million years old). In the south to southeast, close to Ambarawa, and in the north, around Mount Ungaran, andesite igneous rocks (Tma) are exposed that form small mountains, such as Mount Turun, Mount Kendalisodo, Mount Siwakul, Mount Mabang, and Mount Pertapan which are of Middle Miocene age. It was also revealed locally that the Middle Miocene basalt igneous rocks (Tmb) are on Mount Sitapel, Mount Klesem, and Mount Mergi to the east. Around Mount Ungaran, on its slopes, the Kerek Formation (Tmk) is also revealed which is arranged alternately between claystone, napalm, tufaan sandstone, conglomerate, volcanic breccia, and limestone.

There are Pliocene formations and volcanic activity (i.e. Penyatan Formation (QTp) consisting of tufan sandstone, volcanic breccia, tufa, claystone, and lava flows; Kaligetas Formation (Qpkg) which consists of volcanic breccia, tufa, lava flows, tufa sandstone, and claystone; The Squat Formation (Qpj) is composed of hornblende-augite andesite breccia; Kaligesic Volcanic Rocks (Qpk) are composed of olivine augite basalt flows; The Gajahmungkur volcanic rock (Qhg) consists of hornblende-augite andesite lava, Holocene age) on the middle Miocene igneous rocks with unaligned boundaries.

The lava flow of Mount Sumbing (Qls) located on Mount Ungaran is composed of lahari flows from the highlands (hornblende augit andesite) and from the slopes (consisting of lava and young volcanic deposits). Lava deposits consist of inseparable, angular and rounded chunks of rock, with a diameter of up to 2 m; and at the eastern foot of the volcano are deposited alluvium (Qa) deposits consisting of pebbles, gravel, sand and silt.

3 Analysis

Volcanostratigraphy is the systematic grouping of rocks/volcanic deposits then described, arranged to determine the relationship between rocks/volcanic deposits during the formation process. Some assumptions are used in the determination of volcanostratigraphy using satellite imagery, as follows:

1. Composite volcanoes can develop from a single eruption center that develops from small to large, or from a moving eruption center.

2. *Edifice* throws pyroclastic material and lava that will accumulate and deposit around it, so that its distribution is radially dispersed from the main hole.
3. The sequence of events or the relative age of the volcanic units is determined from the law of cross-cut relationships of features seen in satellite imagery.

The volcanostratigraphic method is used with the source of the eruption center that can still be identified, for example the existence of circular features and the morphological shape of the volcanic cone that is clear in satellite images. The sources of the eruption centers that can be identified are closely related to the relatively young age, generally in the Quaternary Period.

On the regional scale of the Mount Ungaran WKP with a scale map of 1 : 100.000 (Figure 4), three Brigade are identified around the Mount Ungaran WKP, namely Sumbing Brigade which is located on the southwest side consisting of Sumbing Crown and Sindoro Crown. Based on the Regional Geological Map of Magelang and Semarang (R.E. Thaden, et al. 1975) Sumbing Brigade consists of the Cleft Volcanic Rock Formation composed of augite-olivine andesite lava, flow breccia, pyroclastic breccia, and lava (R.E. Thaden, et al. 1975). Then on the southeast side of the Mount Ungaran WKP there is Merbabu Brigade which consists of the Merbabu Volcanic Rock Formation which is composed of olivine rocks and augite andesite (R.E. Thaden, et al. 1975). Meanwhile, the Gunung Ungaran WKP is located in the Ungaran Brigade complex which consists of Young Ungaran Crown and Old Ungaran Crown. Mount Ungaran from the regional geological map (Thaden et al., 1975), consists mostly of igneous rocks or volcanic eruptions and sedimentary rocks, the oldest of which is of Middle Miocene age (11.8 – 16 million years) and the youngest is Quaternary (less than 1.8 million years old).

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It was also revealed locally that the Middle Miocene basalt igneous rocks (Tmb) are on Mount Sitapel, Mount Klesem, and Mount Mergi to the east. Around Mount Ungaran, on the slopes also revealed the Kerek Formation (Tmk) which is composed alternately between claystone, napalm, tufaan sandstone, conglomerate, volcanic breccia, and limestone.

Based on the 1 : 50.000 scale map (Figure 5) on the Ungaran WKP, it is identified into 2 Crown (Main Eruption Center):

1. Young Ungaran Crown (Kh. Ung. Young)
2. Old Ungaran Crown (Kh.Ung. Old)

As well as 5 volcanostratigraphic units were identified as Hummock originating from the central eruption and eruption as follows:

1. Pengion Hummock (Gm. Pgn)
2. Songo Hummock (Gm.Sgo)
3. Godong Hummock (Gm. Gdg)
4. Tungku Hummock (Gm. Tgk)
5. Kaligesik Hummock (Gm. Kgk)

Table 1. Volcanostratigraphic Column of Mount Ungaran WKP

Relative Age	Period	Super Brigade	Brigade	Crown	Hummock	Eruption
Kuartar	Post Kaldera	Ungaran	Ungaran		Gm. Pgn	Side
				Kh. Ung Muda	Gm. Sgo	Central
					Gm. Gdg	Central
	Pre Kaldera			Kh. Ung Tua	Gm. Tgk	Side
					Gm. Kgk	Side

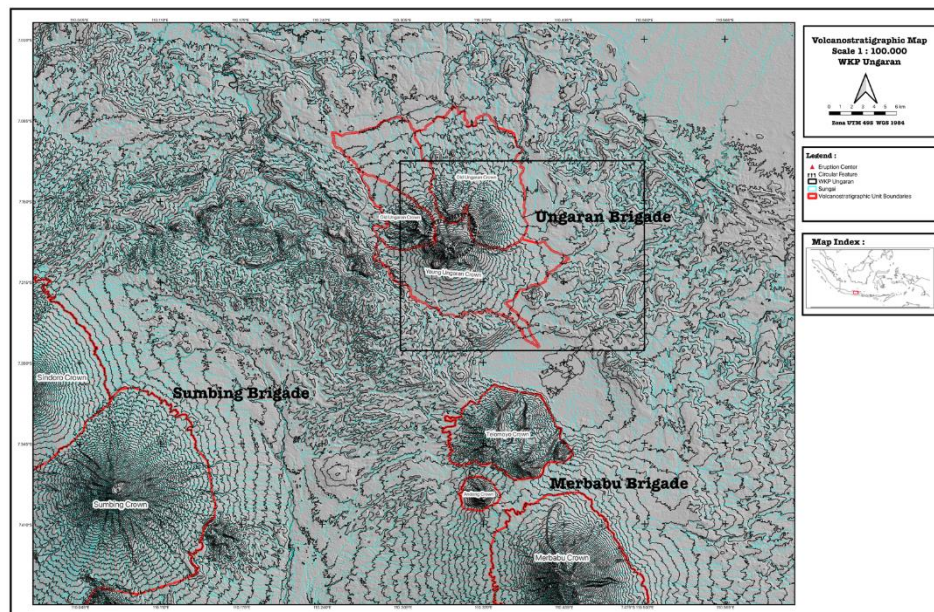


Figure 4. Volcanostratigraphic Map of WKP Ungaran Scale 1:100.000

In general, Brigade Ungaran, which is the focus of the study, is estimated to be 2 periods, namely the Pre-Caldera Ungaran period and the Post Caldera Ungaran period. The Pre-Caldera Period of Organan formed Old Ungaran Crown. Then it is suspected that there was a very large eruption in Khuluk Ungaran Tua which later formed the Ungaran Caldera. Currently, the morphological appearance of the caldera wall from the image is only seen on the northern, northwestern, and northeastern sides which are suspected to be still part of the Old Ungaran Crown Complex, this is also suspected to be part of the Proximal – Distal Facies of the Old Old Ungaran Crown. Old Angkuran Crown which is currently forming on the caldera wall on the ring fault part which is suspected to be a permeable zone/weak zone then a side eruption process that forms a dune occurs in the Northwest: Kali Gesik Hummock and Northeast: Tungku Hummock.

In the Post Caldera period of Ungaran formed Young Ungaran Crown which came from the eruption of the center of the Ungaran Caldera which can be seen from satellite images, this khuluk formed a stratovolcano. Young Ungaran Crown which is suspected to be composed of the intersection of lava flows and pyroclastic products derived from the eruption process. In Young Ungaran Crown, the Pengion Mound was formed which came from a side eruption that formed a flow on the northeast side of Mount Ungaran. Furthermore, on the southwest side of Khuluk Ungaran, young Godong Hummock and Songo Hummock were formed which originated from the eruption center.

Volcanostratigraphic intrusion is limited to the analysis of satellite images to determine the boundaries of the volcanic units, so to determine the details of the volcanic units and eruption products of Mount Ungaran, direct field monitoring data is needed to confirm the results of the volcanostratigraphic studies from satellite images.

4 Conclusion

The geothermal area of Mount Ungaran is part of the Bregada Ungaran system which is related to the formation of the Ungaran Caldera. This geothermal system is indicated to be related to the geological process from the Pre-Ungaran Caldera period to the Post-Ungaran Caldera period. Bregada Ungaran is estimated to consist of old formations (Old Ungaran Khuluk) such as Hummock Kaligesik and Hummock Tungku, as well as young formations (Young Ungaran Crown) such as Pengion Hummock, Songo Hummock, and Godong Hummock.

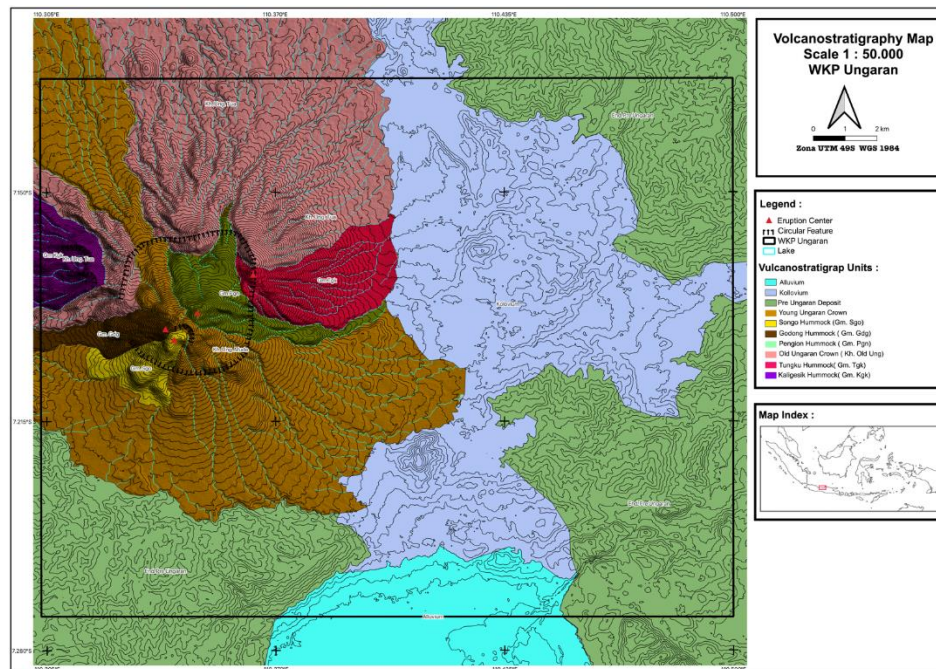


Figure 5. Volcanostratigraphic Map of WKP Ungaran Scale 1:50.000

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