Cycloclypeus (Katacycloclypeus) annulatus MARTIN.
Lepidocyclina (Nephrolepidina) rutteni V. D. VLERK.
Lepidocyclina (Nephrolepidina) jerreroi PROVALE.
Lepidocyclina (Nephrolepidina) injlata PROVALE.
Miogypsina polymorpha RUTTEN.
Miogypsina thecideaeformis RUTTEN.

The maximum thickness of the Ojo Beds is 350 m. This horizon is still of middle-miocene age. It can be correlated with the transgressive basal layers of the Sentolo Beds farther West, in Central Java, which are also characterized by typical vitreous tuff intercalations. The Ojo tuffs belong to a renewed stage of volcanism in the Solo Zone, viz. that of the "Banjak" volcanoes, which produced also the hornblende-andesitic Banjak Beds in the Kendeng Zone.

The Ojo Beds are conformably succeeded by the **Wonosari Beds**; platy marls and limestones, passing southward into the more massive reef-limestones of the Gunung Sewu. The latter contain: *Lepidocyclina* sp., *Miogypsina polymorpha*, M. *thecideaeformis.*

In the basins of Wonosari and Baturetno the Wonosari limestones are conformably succeeded by the **Kepek Beds** *(Globigerina-maris)* in which rarely larger Foraminifera were found *(Lep. flexuosa)* due to unfavourable facies. Moreover, *Vicarya callosa*, one of the key-fossils of the Preanguerian ($T.f_3$), was found in these Kepek Beds.

The Kepek marls are about 200 m thick in the Wonosari basin, but southward their facies seems to change into that of the Wonosari reef-limestones. The latter attain a thickness of 800 m in the Gunung Sewu. The platy limestones and marls of the Wonosari basin are the equivalent of the Sentolo limestones farther West (West-Progo Mts, Central Java).

Thereafter the subsidence of the Southern Mts belt came to a halt. The top of the Wonosari (Kepek) limestones remained at sealevel for the rest of the Neogene and the older Pleistocene. No erosion took place and no Karst topography was as yet formed during this stretch of time, as has been pointed out by LEHMANN (1936, p. 64).

Finally, the Java-geanticline was arched up again. The southern Mts were elevated and tilted southward, forming its South flank.

FIG. 268 on PLATE 34. *Geological sketchmap of the Surakarta area.*

FIG. 269 on PLATE 28. *Geological sections of the Surakarta area.*

During this uplift the crest of the geanticline, which was situated in the Solo Zone, broke down and slid northwards, as will be discussed later on.

The South flank of the geanticline stayed behind and broke off along a number of step faults and flexures, forming "antithetic" fault blocks[2]). These step faults are sometimes developed as flexures in the softer neogene strata near the surface, and the subsequent erosion transformed them into escarpments. Tilted blocks at the transition between the Southern Mts, and the Solo Zone are found, for instance, near Wonogiri (Plopoh Range) and Tirtomojo (Kambengan Range). These block-faulted mountain ranges are separated from the main block of the Southern mountains by asymmetrical depressions, like that of Wurjanto-Tirtomojo.

This phase of uplift, tilting, and block faulting occurred during the Middle Pleistocene. Meanwhile, in the Solo Zone the synorogenic Kabuh Layers were deposited, containing the famous Trinil fauna with *Pithecanthropus.*

At first a consequent, southward directed drainage pattern developed on the surface of the tilted block of the Southern Mts and Karst-phenomena were formed in the massive Wonosari limestone.[3]) Thereafter, in the Upper Pleistocene, a further warping of this tilted surface has taken place and the basins of Wonosari and Baturetno were formed, as was demonstrated by LEHMANN (1936).

Due to this later warping the drainage of these basins took a reversed course (towards the North) and became part of the catchment basins of the Opak- and Solo Rivers. For instance, a river-valley between Baturetno and the Indian Ocean at present is a dry stream bed, while the surface water flows northward to the Solo River. One of the left hand tributary rivers of the upper course of the Solo in the Tirtomojo depression flows first over the elevated peneplain of Old-andesite rocks at more than 1000 m above sealevel (Gondanglegi, 1,098 m). Then it dashes down with rapids and falls along the escarpment until it reaches Tirtomojo at 171 m above sea.

This later warping of the surface of the Southern Mts can be interpreted as the continuation of the breaking off, tilting and northward sliding of blocks from this South flank of the Java geanticline, which began in middle pleistocene time. This will be discussed here after.

---

[2] Term used by H. CLOOS, "Einfuhrung in die Geologie", 1936, p. 267.

[3] In this old peneplain, VON KOENIGSWALD found a middle-pleistocene fauna with *Tapirus* and *Rhinoceros*, species which must have lived in moist forests. The name "Wonosari" means "fine forest", which is also an indication that this area has changed very recently into the present barren Karst-region.

These basins in the Southern Mts have an asymmetric structure. On the northern side of the **Wonosari Basin** older miocene strata are exposed, whereas the youngest member of the miocene sequence (the Kepek Layers) has its greatest distribution in the southern part of the basin (South of Wonosari), where it abuts against a steep flexure of the surface of the Gunung Sewu. The drainage of this southern part of the Wonosari Basin (Plajen-Wonosari-Semanu) is still southward towards this flexure of the Gunung Sewu. LEHMANN (1936, p. 43; see also p. 28-29) describes it as a sinus-flexure of the peneplain, accompanied by small faults, dipping towards the basin of Wonosari, the deepest parts of which lie immediately at the foot of this flexure (see also the morphological map of the Southern Mts by LEHMANN, 1936, Plate VI). This flexure has an arcuate course between Imogiri in the West and the Panggung Massif in the East, being concave to the Northwest. Most probably it masks a normal, northward directed (stepped) fault in the basement complex. On the northern side of the basin, between the Ojo River and the Djiwo Hills, the miocene sequence of strata is compressed, forming a broad anticlinal structure, the axis of which lies North of the escarpment of the Baturagung Range. The northern limb of this anticline is found only at its eastern end, some kilometres ESE of Djiwo. For the rest it is absent. South of the Djiwo Hills, near G. Geneng, a northward upthrust at the base of this anticline has been observed.

BOTHE supposed that the northern limb of the anticline was removed by erosion (1929, p. 11). However, it is difficult to understand how this enormous series of miocene strata, 4000 m thick, could be removed by the young quaternary denudation, while the southern limb remained intact as a high cuesta in the landscape.

The situation might be explained by the following sequence of events:

In the Middle-Pleistocene the Java geanticline was arched up. During or immediately after this uplift the axial zone (on which the Djiwo Hills were situated) broke down and slid northward. A zone of normal, northward dipping faults originated between the Djiwo Hills and the Gunung Kidul. This was the initial fault escarpment of the Baturagung Range. Thereafter, in the Upper Pleistocene, another block broke off from the Southfiank, viz. the block underlying the present Wonosari Basin. This block slid also northward and compressed its northern margin. At this stage the original fault-escarpment of the Gunung Kidul was transformed into a one-sided anticline, which was thrust against the massif of the Djiwo Hills. The Baturagung anticline extends from the Panggung Massif around the margin of the Southern Mountains to G. Sudimoro near Imogiri, being convex to the North-west. On the NW side of the Panggung Massif two other anticlines are found with a WSW-ENE, and SW-NE trend. These anticlinal structures can also be considered as products of the compression exerted by northwestward slipping blocks.

Similar events occurred in the **Baturetno Basin,** East of the Panggung Massif. The marginal flexure on the southern side of the Baturetno Basin is much narrower, having an E-W diameter of only 10 km, while it is strongly concave to the NNE. The two arms of the flexure are more or less parallel, extending between Eremoko and Pratjimotoro on the western side of the Baturetno Basin, and along the West foot of the G. Bromo near Giritontro on its eastern side. The southward tilting of its floor is not evident as the drainage pattern is already completely directed towards the Solo River in the North. The northern part of the Baturetno Basin, North of the line Eromoko-G. Bromo, forms part of three parallel basins between tilled fault blocks, so that a number of lateral enlargments on both sides of the basin are formed.

The faults separating these blocks are exposed West of Eromoko-Wurjantoro, where they appear as a succession of stepfaults, dipping to the NE, cutting off the Panggung Massif, and along which the Ojo Beds subsided northeastward.

The Panggung Massif of Old-andesites was left behind between the crescentic Wonosari fault, concave to the NW, and the arcuate stepfaults of the Baturetno Basin, which are concave to the NE. The Panggung Massif is the spur of intersection between both fault- and flexure systems. On its top the peneplain of the Southern Mountains has been preserved at a height of more than 700 m above sealevel, while the surrounding area subsided to a level of 200-300 m. With the exception of the fold structures North of the Wonosari Basin the miocene strata of the Southern Mts have never been actually folded by compression. They were only subjected to tilting, warping, faulting and flexuring during the vertical oscillatory movements of this area in neogene and quaternary time.

The block-faulting movements along the northern side of the Southern Mts are older than the formation of the Old Lawu Complex North of it, for the mantle of this volcano abuts against the escarpment of the Southern Mts and partly overflows them. The Old Lawu belongs to the Noto-puro stage of volcanism, which is assigned to the upper part of the Middle-, and the lower part of the Upper-Pleistocene, as will be shown afterwards.

The middle-pleistocene Kabuh Beds of the Ngawi Subzone, which are unconformably overlain by the Notopuro breccias, are a series of cross-bedded sandstones, gravels, and conglomerates. Most probably these Kabuh Beds were formed during the uplift of the Southern Mts and the formation of fault escarpments along its northern edge, being a typical synorogenic formation.

The middle-pleistocene Kabuh Beds do not yet contain ejectamenta of the Old Lawu. Thus the age of the rise of the Southern Mts and the subsidence of the Solo Zone is Middle Pleistocene, and the volcanic activity began after these movements, in the Young Pleistocene.

East of Popoh Bay the northern escarpment is partly buried by the holocene volcanoes, or the latter abut against it, so that for this section we can only say that the elevation took place before the Holocene. Therefore, the uplift of the Southern Mts might be somewhat younger here than in the Opak-Progo section. We specially mention this possibility as it appears that also the main phase of folding of the eastern part of the Kendeng anticlinorium is somewhat younger (post-Middle Pleistocene) than that of its western part (Lower-Middle Pleistocene).

2. THE SOLO ZONE

Technically, this zone represents the highest part of the geanticline of Java, as appears from the exposure in its central axis of the oldest (pre-tertiary and lower tertiary) formations, viz. in the Djiwo Hills near Klaten. Physiographically, however, it now forms a depressed belt with giant volcanoes and fertile plains. Apart from the Djiwo Hills, exposures of the tertiary sediments underlying the quaternary volcanoes are only found in the San-giran dome, North of Solo, and on the North flank of the Lawu.

The **Djiwo Hills** consist of pre-tertiary, partly cretaceous, phyllites and schists, unconformably covered by eocene limestones and sandstones. The meta-morphic fades of the Pre-Tertiary is partly due to the contact aureole of a microdioritic and diorite-porphyritic intrusion. Isolated blocks of *Orbitolina*-limestone prove the presence of the Cretaceous.

Similar intrusions occur in the Lokulo area of Central Java, belonging to the same tectonical zone as the Djiwo Hills. In the Lokulo area the age of the gabbro-dioritic intrusions is probably intra-miocene. Those of the Djiwo Hills might be of lower-miocene age, as has been discussed on p. 556.

The row of volcanoes **Merapi-Telemojo** occupies the western end of the Solo Zone. They are situated on an important transverse fault which is concave to the West. This fault forms the boundary between East- and Central Java. Its southern part cuts off the Southern Mts along the Opak River South of Djokjakarta, while its northern part extends via the Genteng trough to the Ungaran volcano. This transverse fault is capped by a row of volcanoes, from North to South: Ungaran, Soropati-Telemojo, Merbabu and Merapi.

In four places this transverse fault is intersected by longitudinal faults:

1. Its northern end (formed by the Glagah fault) is cut off by the monoclinal flexure or fault, bounding the Tjandi Hills on their northern side (see fig. 309).
2. South of the Ungaran, between the Genteng Graben and the Banaran pass, it intersects with an E-W fault or flexure, which forms the boundary between the eastern end of the North-Seraju Range and the Magelang depression.

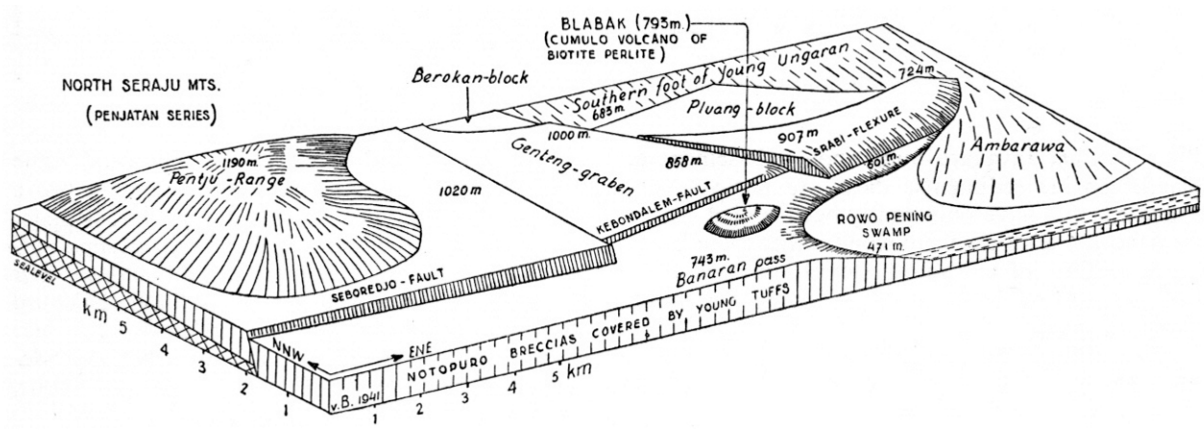

FIG. 270. *Schematical blockdiagram of the Genteng Graben near Banaran.* (From VAN BEMMELEN, 1943, fig. 25, p. 32)

The Genteng Graben is distinctly younger than the longitudinal fault, causing the northward shift of the Kebondalem section of this longitudinal fault with respect to the Seboredjo section to the West, and the Srabi flexure to the East.

3. The Merapi cone and its parasitic Bibi volcano are situated at the intersection between this transverse fault and the westward extension of the "Simo fault" along the southern side of the West-Kendeng Ridge.
4. Near Prambanan it passes across the longitudinal fault system between the Solo Zone and the Southern Mountains.

The Old-Ungaran, the Soropati and possibly also the Old Merbabu are of middle- to upper pleistocene age; their eruption products formed Notopuro breccias. The older part of the Merapi volcano is younger than the Notopuro stage, and is at least partly holocene, while the active Merapi cone was built up since 1006 A.D.

There is a gradual development of volcanism along the transverse fault from North to South, starting in the North with the oldest or proto-Un-garan in the Lower Pleistocene and ending in the South with the very active Merapi volcano.

The young quaternary volcanoes in the Solo Zone in East Java are built upon a basement of plastic marine sediments; these are not yet consolidated, and have only gently been folded during the Middle Pleistocene. No wonder that these heavy accumulations of volcanic material, amassed upon such a poor foundation, were subjected to gravitational collapses.

We mentioned already in the eastern spur of Java several instances of such volcano-tectonic collapses. As will be shown hereafter, the quaternary volcanoes of this section of the Solo Zone also