THE CONGLOMERATES AND GRITS OF KALDURGA, KADUR DISTRICT, MYSORE.

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1. *Introduction.*

SIXTEEN years ago, the writer had the opportunity of examining parts of the Kaldurga area, especially the conglomerates occurring therein, in the company of the late Professor P. Sampat Iyengar, than whom one could not expect a better exponent of the autoclastic origin of the conglomerates of Mysore. He was struck then by the size and degree of rounding which many of the pebbles exhibited and wondered whether pressure alone could have been the cause for the formation of such a sedimentary looking conglomerate. In 1932, he visited parts of the Kadur District, when a halt was made at Jodikatte, and the conglomerates and associated rocks were examined in detail, and a large collection of the conglomerate and the included pebbles was made. The material was studied in the Geological laboratory of the University of Glasgow, and this paper is the record of work which was mainly done there. The writer visited the area once again this year and was able to observe several new features presented by the conglomerates and grits, which are incorporated in this paper.

2. *Previous Work.*

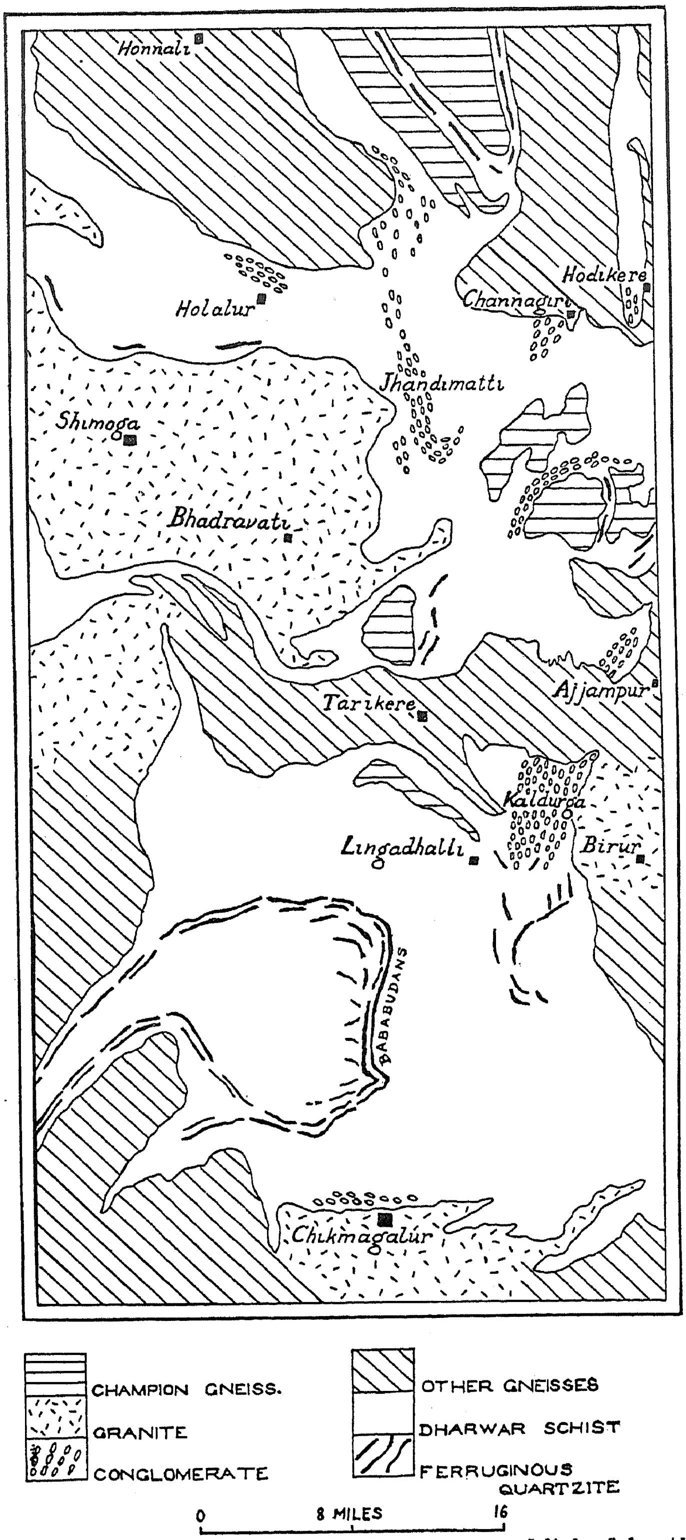
Bruce Foote, while he was a Deputy Superintendent of the Geological Survey of India, made a traverse across the Mysore State, and has given the earliest description of these conglomerates. He noticed the rugged nature of the hills formed by these rocks, which, according to him, resemble "typical granitoid-gneiss hills". He describes the rock as having a coarse mottled structure due to the presence of "enormous numbers of well-rounded pebbles of a granite or compact granite-gneiss. The size of the included stones ranges from small pebbles to large boulders, all enclosed in a greenish-grey foliated chloritic matrix" (R. Bruce Foote, 1882, p. 195). He was later appointed as State Geologist in Mysore, and after his retirement, his observations were published by the Mysore Geological Department as a Memoir. In this work, he has divided the conglomerates into two series, a lower, composed of coarse shingle lying in a "schisty or clayey matrix" and an upper formed of coarse shingle cemented by a "very strong sandstone matrix" (R. Bruce Foote, 1900, pp. 29-31).

A brief reference to these conglomerates was made by Wetherell while dealing with the Geology of the Tarikere valley. He noticed the resemblance which these bore to the conglomerates found further north in the Ajjampur area (E. W. Wetherell, 1903, p. 97).

Though Slater accompanied Bruce Foote to Kaldurga in the year 1896, it was only in 1906 that he gave any description of these conglomerates. As the result of his examination he found that pebbly beds alternated with very fine-grained bands. The pebbles were of granite, granophyre, keratophyre, hornblende schist, quartzite and ferruginous quartzite. Regarding the matrix he states, "the further the matrix of these conglomerates is studied microscopically, the more do they appear to be a phase of an igneous rock—the quartz porphyry" (H. K. Slater, 1906, p. 4). He considered that the north-eastern arm of the Kaldurga conglomerates if continued in that direction would connect the conglomerates on the northern side of Honnegudda (△3338) of the Ajjampur area and that the two might be parts of the same formation, since the pebbles and the matrix were similar. The Kaldurga conglomerates had also a marked resemblance to those occurring near Jhandimatti between Bhadravati and Channagiri (Fig. 1).

Regarding the origin of these conglomerates, Slater was not quite decided as can be seen from the following quotation: "Where granite or quartz porphyry intruded other members, *i.e.*, intermediate lava flows of which numerous pebbles exist—pebbles of schist would result through pressure and movement, portions of both the intruding and intruded rock being finely comminuted, would go to form either a felspathic and gritty or chloritic and calcareous matrix. The variety of fragments—granite, quartz-porphyry, quartzite and keratophyre—may be accounted as fragments of the adjacent schist which have been thus fractured and penetrated by the granite or quartz-porphyry, and the whole subsequently crushed. But they might equally well represent a sedimentary grit" (H. K. Slater, 1906, p. 5).

It was, however, ten years later, that a decisive opinion regarding the origin of these conglomerates, was given. Dr. Smeeth, who was the Director of the Mysore Geological Department, after an examination of the Kaldurga area arrived at the conclusion that the conglomerates were autoclastic and not sedimentary, though he admits that "a few portions which show very rounded pebbles of quartzite in a schistose matrix are difficult to explain" (W. F. Smeeth, 1915, p. 25). He considered it probable that the Ajjampur conglomerates corresponded with those of Kaldurga, the two exposures being separated by the gneiss and granite of the Tarikere valley.



(Adapted from the Geological Map of Mysore, published by the Mysore Geological Department.)

FIG 1. Geological sketch map of a portion of the Shimoga schist belt, showing the distribution of the conglomerates.

In 1916, Sampat Iyengar made a brief reference to these conglomerates, while describing the schistose rocks of the Bababudan area (P. Sampat Iyengar, 1916, p. 134), but it was in the following year that he undertook a detailed study of these rocks. He emphasised the autoclastic origin of the conglomerates which he considered as "a mixture of various complexes brought about by crush and shear movements operating on the previously existing schist rock and on the igneous intrusives into them" (P. Sampat Iyengar, 1917, p. 115). He was of opinion that the brownish gritty mica chlorite schists and the dark green chlorite schists were the crushed and altered phases of the Champion gneiss which is intrusive into pre-existing hornblende schists, amphibolite and some chlorite schists. Into this complex the Tarikere granitic gneiss is supposed to have intruded, tongues of this gneiss which penetrate the schists having been converted along shear zones into conglomeratic masses. He collected pebbles of granite, reef quartz, quartzite, dark green chlorite schist, limestone, amphibolite and hornblende schist.

In all previous reports dealing with this and with the adjacent Ajjampur area, the opinion was expressed that the Kaldurga and Ajjampur conglomerates formed one continuous formation which was later interrupted by the intrusive gneissic granite of Tarikere. Sampat Iyengar did not agree with this view since he considered the Kaldurga conglomerates and the Tarikere gneissic granite as one and the same. According to him, "it is quite probable that the Tarikere gneissic granite at its northern end also did send into the schists several tongues which like their compeers in the south have also become autoclastic conglomerates through the operation of the same forces of nature" (P. Sampat Iyengar, 1917, p. 116).

In his annual report of the work of the Mysore Geological Department for the year 1916, Smeeth endorsed the opinions expressed by Sampat Iyengar, regarding the origin of the conglomerates. He agreed that "the bands of intrusive gneiss, the crushing and shearing of which have given rise to much of the conglomerate, are not distinguishable from the gneiss of the Tarikere valley" (W. F. Smeeth, 1917, p. 33). This view of Smeeth and Sampat Iyengar regarding the identity of the conglomerate and the Tarikere gneiss has, however, been contradicted by Jayaram, who, during the revision survey work, examined the junction of the Tarikere granite with the conglomerate series of Ajjampur and found that "the granite proper which tongues into the schistose series does not form part of the conglomerate series" (B. Jayaram, 1923, p. 26).

During the field season of 1918-19, Jayaram examined these conglomerates. He describes them as "granite-porphyry conglomerate", "intermediate granite-porphyry conglomerate", and "chlorite-keratophyre-schist conglomerate"; these types are supposed to be gradational, one merging into the other. The "granite-porphyry conglomerate" is, according to him, "very instructive for studying the pebble formation in an igneous rock, which must have had a viscous flow condition favourable for the formation of phenocrysts, knots, acid and basic segregations and schlieren that have on subsequent shearing assumed the conglomerate form" (B. Jayaram, 1922 *b*, p. 64). The term "grit" has been used in this report several times but without any sedimentary significance as he considers it "a variant of the micro-granite".

In his Presidential address to the Geology Section of the Indian Science Congress at Nagpur, Sampat Iyengar stated that at its contact, the Peninsular gneiss has imposed an autoclastic structure on the Champion gneiss (P. Sampat Iyengar, 1920, p. 7).

No further work has been done since then on these conglomerates, and so the autoclastic theory remains at present the official opinion of the Mysore Geological Department regarding the origin of the Kaldurga conglomerates. Middlemiss has remarked on the unanimity with which this view has been advocated by the Mysore geologists in his Presidential address to the Geology Section of the Fourth Indian Science Congress held in Bangalore (C. S. Middlemiss, 1917, p. cxcvi).

3. Geology of the Area.

Before describing the conglomerates and grits, it is proposed to give a brief account of the geology of the area. The Kaldurga conglomerates form part of the Shimoga belt of the Dharwar schists. The schist belt in the neighbourhood of the conglomerates is composed of epidiorite, spilite, keratophyre, chlorite schist, calc-chlorite schist, mica-chlorite schist, grits, quartzite and magnetite quartzite. Small outcrops of limestone, amphibolite and talc schist occur. Intrusive into the schists are quartz veins, Champion gneiss, Peninsular gneiss, Kadur granite and dolerite dykes.

Epidiorite.—A portion of the Lingadhalli traps appears at the extreme south-west of the area under consideration. This epidiorite varies in texture from a very fine-grained and tough rock to a coarse one exhibiting poikiloblastic structures. The outcrops of this rock about half-a-mile north-east of Lingadhalli abound in rounded or oval "spots" which were considered by Slater to be "pseudo-amygdules due to the crushing of quartz phenocrysts" (1906, p. 12) or *in situ* alterations of porphyritic crystals of hornblende and not true amygdules (H. K. Slater, 1908, p. 48). According to Sampat Iyengar, some of them were *in situ* alterations of plagioclase phenocrysts and some due to the brecciation of quartz or epidote veins

(P. Sampat Iyengar, 1908, p. 70). A detailed study of these rocks by the writer has shown that these "spots" are true vesicles filled in by various secondary minerals (C. S. Pichamuthu, 1932, pp. 127-137). An interesting feature of some of these amygdales is the occurrence of plagioclase felspars as infilling minerals. It is probable that these have been formed by the alteration of some zeolitic mineral which might originally have occupied these cavities (C. S. Pichamuthu, 1933, p. 345).

The epidiorite is composed essentially of a pale green hornblende which is often fibrous. Plagioclase, when present, is of an acid variety. A small quantity of quartz is usually present. Granular and idioblastic epidote is common, as is also ilmenite, invariably altered to leucoxene. Some varieties contain abundant chlorite.

Spilite, Keratophyre.—As the result of the examination of the rocks of this area, both in the field and under the microscope, the writer is of the opinion that there is a spilitic suite of rock characterised by the presence of albite and acid oligoclase. Chemical analyses of some of these types are under progress and when they are complete, it is hoped that the relationships of the different rocks occurring here, will be better known. Some of the rocks which have been mapped as the Lingadhalli traps are spilitic. About half-a-mile south-east of △3179, a vesicular spilite occurs. The microsections of this rock are stippled throughout with fine leucoxenic grains, which are specially concentrated around the amygdales. Felted aggregates of fibrous hornblende and laths of albite form the main constituents. The amygdales are filled by a pale green pleochroic epidote, quartz and chlorite. The epidotes exhibit a peculiar form of corrosion. Sometimes circular portions of the epidote are removed and replaced by quartz ; in other cases, a remnant of the epidote is left in the centre of these circular areas. The edges of the epidote which have thus been attacked exhibit a scalloped outline.

The term " Keratophyre" has been used in a very loose sense in many of the reports of the Mysore Geological Department, to describe rocks which have no textural or mineralogical resemblance to the type variety. It has practically come to be synonymous with a calc-chlorite schist. In this paper, the term is confined to those rocks which contain laths of albite and which exhibit a trachytic or bostonitic texture ; in some cases where the albite laths are not flow-oriented, the texture approaches that of a basalt or fine-grained dolerite. Chlorite occurs in varying proportions. Calcite is invariably present. Very good exposures of this rock were noticed by the writer on the flanks of the small conical hill, about half-a-mile south-east of Lingadhalli. The rock is dark in appearance but the specific gravity is as low as

2·68. Overlying the keratophyres here, exceedingly fine examples of albite schists occur. Porphyroblasts of clear albite are found in a sericite chlorite matrix.

Amphibolite, Talc-schist.—Exposures of amphibolite and talc-schists are seen near Jodikatte. The amphibolites are composed mainly of a pale hornblende. Grains of calcite and iron ore are common. The talc-schists occurring outside the conglomerate area and adjoining the granites, probably represent shear zones.

Limestone.—A small patch of impure limestone outcrops to the south-west of Jodikatte. It contains fuchsite and is traversed by numerous thin veins of quartz. The rock is very rich in inclusions of rutile.

Quartzites, Banded ferruginous quartzites.—There are numerous runs of quartzites associated especially with the chlorite schists. They conform generally to the directions of strike and dip of the schists. They are composed essentially of a granoblastic aggregate of quartz grains. Chlorite occurs frequently ; fuchsite was noticed in a few runs of the quartzites near Jodikatte. Tourmaline is sometimes present. Muscovite, biotite, pyrites and magnetite are other minerals which occur in the quartzites. Some of the quartzites show faint traces of banding and this becomes conspicuous as the iron content increases. Typical banded ferruginous quartzites occur on the hills to the east of Lingadhalli and on the small rise near Huvinhalli.

Gneiss.—The oldest gneiss occurring in Mysore has been called the Champion gneiss. A strip of this is seen to the north of Lingadhalli. In the map of Mysore published by the Geological Department, the conglomerates are also shown as Champion gneiss, a view with which the writer finds it difficult to agree. The Champion gneiss is considered to be intrusive into the Dharwar schists but the term "Champion gneiss" has been used in Mysore with such different meanings and to include so many types of rocks that it is difficult to comprehend what exactly is meant by it. A good idea of the various rock types which are supposed to be allied to the Champion gneiss, may be obtained from Sampat Iyengar's Presidential address to the Geology Section of the Indian Science Congress (P. Sampat Iyengar, 1920, pp. 2-13). The Peninsular gneiss is later in age than the Champion gneiss and includes the gneissic granites of the Tarikere valley, as well as the gneisses to the east of the conglomerate area.

Granite.—The Kadur granite is intrusive into the Peninsular gneiss. The intrusion of this granite has been accompanied by pneumatolytic action resulting in tourmalinisation and greisening. Examples of schorl and greisen were noticed by the writer about half-a-mile north-west of Jodikatte.

Granodiorite.—An outcrop of this rock occurs on the flanks of the hill north of the 4th milestone on the Birur to Lingadhalli road. Its relationship with the other rocks was not clear. Big grains of quartz are present, showing undulose extinction. The plagioclase which is mainly albite, occurs as large crystals; the crystals are invariably bent or broken, the fractures being healed by chlorite and iron ore. There is abundant biotite undergoing alteration to chlorite. Apatite is the chief accessory.

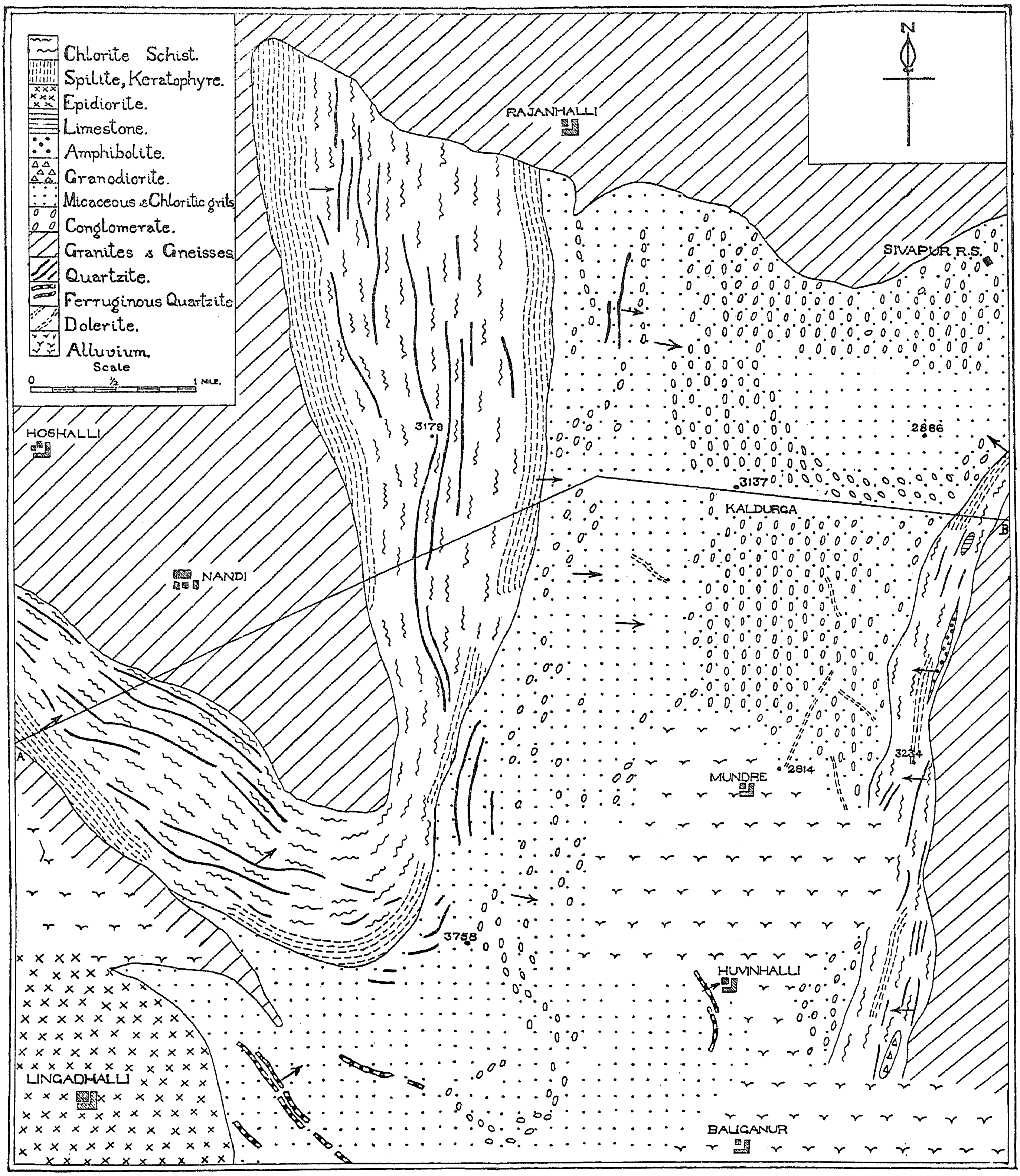
Vein quartz.—There are many runs of massive white quartz. These are related to the different acid intrusives and are not therefore all of the same age.

Dolerite.—A few dykes of normal dolerite occur in the area.

4. *Tectonics.*

The geological structure of the area as well as the general succession of the rocks occurring here, may be seen from the map (Fig. 2) and the section (Fig. 3). The oldest rocks are the chlorite schists and mica chlorite schists. Spilites, keratophyres, quartzites and banded ferruginous quartzites occur interbedded with these schists. The schists pass upwards into grits and conglomerates. The occurrence in the conglomerates of pebbles of granite and gneiss, which differ from the granites and gneisses of the area in the absence of potash felspars, raises an interesting problem. These pebbles must have been derived from rocks which are older than the conglomerates but so far the writer has been unable to trace any outcrops of these rocks. The abundance of acidic rocks in the upper chloritic division is difficult of explanation if they are considered to be derivatives of the Champion gneiss and hence later than both divisions of the Dharwars. Smeeth therefore suggested that some of them should be "associated with a period of granitic intrusion still earlier than the Champion gneiss, but of which period the primary granite or gneiss has not been identified and separated. Remnants of the earlier gneiss might easily remain amongst the very varied types which are at present included under the designation 'Champion gneiss' " (W. F. Smeeth, 1924, p. 158). It is probable that these pebbles discovered by the writer in the Kaldurga conglomerates, are derived from this 'Pre-Champion gneiss'. The Peninsular gneiss is intrusive into the schists and the Kadur granite intrudes this gneiss. Dolerite dykes are the youngest rocks in the area.

The dip of the rocks is uniformly towards the east, except near the eastern margin of the area, where the beds dip westward. There is an overfold in the western portion, by the denudation of which the Nandi-Hoshalli valley has been formed. The beds are folded into a syncline on the east.



(Modified by the writer from the map of Sampat Iyengar, *Recs. Mys. Geol. Dept.*, Vol. 15.)

FIG. 2. Geological sketch map of Kaldurga and surroundings.

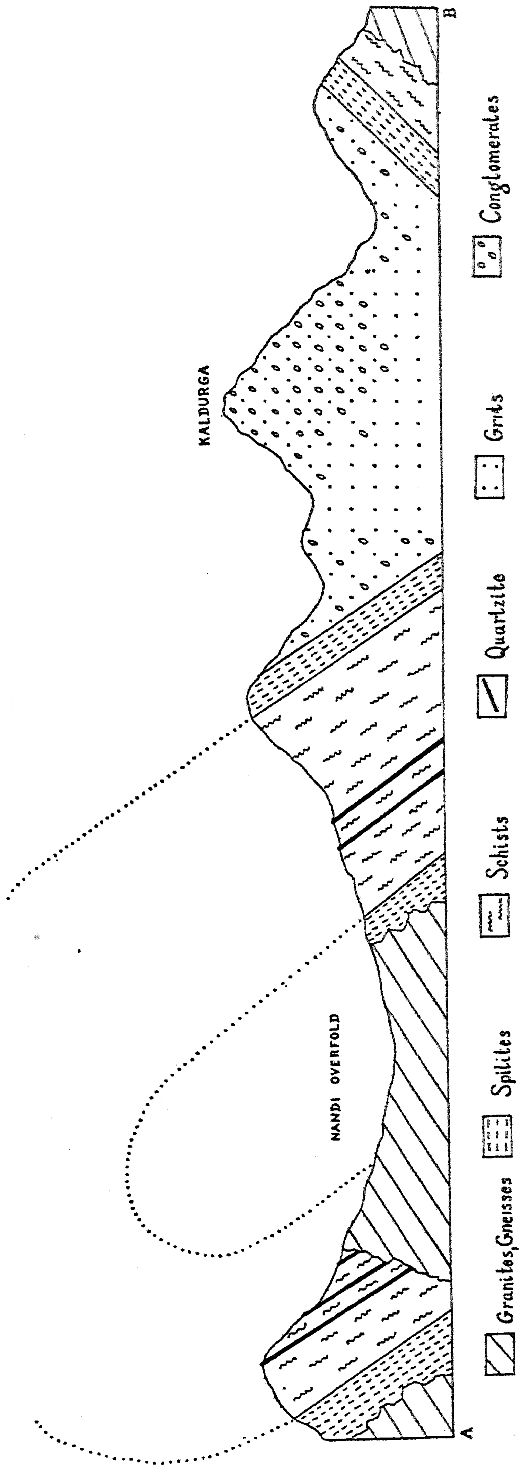


FIG. 3. Section along AB in Fig. 2.

5. *The Conglomerates and Grits.*

The conglomerates and grits overlie the chloritic schists and the associated spilites and keratophyres. Sampat Iyengar, in his map of this area, has differentiated chlorite schists and brownish mica chlorite schists. Though in places one comes across brownish coloured schists and in other places dark green chlorite schists, the boundary between the two is not so sharp as has been represented on his map. Under the microscope, many of his "brownish mica chlorite schists" show very little mica; they are composed almost entirely of chlorite.

The conglomerates and grits can, however, be divided into two series: a lower, characterised by the abundance of chlorite, and an upper, which is more gritty and in some cases felspathic. The lower division may be described as a greywacke; the upper varies from quartz schist to a felspathic grit or arkose. The lower division is typically schistose, the strike and dip being ordinarily well marked. In contrast to this, the exposures of rocks belonging to the upper division are bouldery, and have the characteristic appearance of granitic outcrops. Many of the huge boulders stand out as prominent tors and form the range of hills from Rajanhalli to Mundre.

The lower chloritic schists and grits present no unusual features. Biotite has frequently been formed from the chlorites. Due to crushing these schists often possess, under the microscope, the typical appearance of a sheared grit (Plate XXIV, Fig. 1), the quartz grains forming tiny "eyes" and the flaky minerals encircling them. Amber yellow rutile grains are often abundant.

In the conglomerates of the upper division, it is not uncommon to see pebbly bands alternating with very fine-grained non-pebbly bands. To a casual observer these bands suggest rocks of different composition, but an examination of sections cut from them proves their identity. The finer bands represent the material which serves as the matrix in the pebbly layers. In some cases chlorite, biotite and muscovite are set in a granoblastic matrix of quartz. The flaky minerals vary in proportion; when they are abundant, a fairly regular parallel arrangement is seen and the rock may then be called a quartz schist. Very often, grains of plagioclase felspar, usually albite or acid oligoclase, are present; but microcline was not observed at all, and since this is the most resistant of the felspars to alteration, it is to be concluded that the mineral never occurred in these rocks.

Extremely fine varieties of grits are seen on the hills about a mile west of Baliganur. The outcrops in this place exhibit graded bedding. The rock here has layers about a foot in thickness one overlying the other. Each layer starts with a more or less coarse pebbly character and gradually becomes finer and finer, till the next layer again starts abruptly with coarse pebbles, grading on into fine (C. S. Pichamuthu, 1935, p. 431). In some cases a crude current bedding was observed which also exhibited graded bedding.

The coarse grits collected here proved very interesting material for study. In hand specimens, they are found to be composed of small fragments of various types of rocks. This character is very well seen under the microscope (Plate XXIV, Fig. 2). Many of the individual grains in the grit are composed of quartzite, but small fragments of granite, spilite, keratophyre, phyllite and vein quartz are also seen practically in every section. The rock has been subjected to pressure, resulting in many of the fragments being flattened and drawn out, but their boundaries are quite distinct and do not merge with the matrix.

6. *The Pebbles.*

The conglomerates contain pebbles of various sizes. In some cases they are as much as 12″ to 18″ in diameter, and they grade down into very small sizes in the pebbly grits. In certain areas, pebbles are abundant, and in others, their occurrence is sporadic. In the same outcrops, it has been noticed that some bands are very rich in pebbles and that they alternate with bands which do not contain any. The pebbles are of various shapes but almost every one of them exhibits some degree of polishing. Oval and rounded pebbles are of frequent occurrence.

The conglomerate is often crowded with a large number of pebbles of a varied petrographical character. Plate XXIII is a photograph of a specimen about 6″×9″ in size, obtained from the south of Kaldurga. It contained nearly thirty pebbles composed of such different types as gneiss, granite, microgranite, pegmatite, quartzites (two varieties), quartz schist, quartz-felspar porphyry, and vesicular spilite. The following description of the pebbles collected from the Kaldurga conglomerates illustrates the great variety of the rock types which have supplied the pebbles.

Granite.—Pebbles of granite have been reported to occur by practically every geologist who has visited these conglomerates. The writer has examined the slides of pebbles collected by himself, as well as those preserved in the museum of the Mysore Geological Department, and in all these cases, the felspar is albite or acid oligoclase. No orthoclase or microcline is met with. Quartz and biotite (which is sometimes altered to chlorite) are present. Such rocks have been designated soda-granites, but since this term has also been applied to granites in which there is more soda than potash, and since quartz bearing acid plagioclase rocks are tonalites, Johannsen prefers to call these plutonic rocks, which are granite-like in appearance but contain only a trace or no potash felspar, as sodaclase-tonalites (A. Johannsen, 1932, p. 373).

Gneiss.—The light-coloured pebbles with gneissic banding, also do not contain orthoclase or microcline. The essential minerals are albite, quartz and biotite. Muscovite is commonly present. Apatite, zircon and rutile are the chief accessory minerals. Some of the sections exhibit a diablastic structure due to albite-quartz intergrowths. The biotite is frequently altered to chlorite; that the mica is titaniferous is evidenced by the sagenitic webs of rutile sometimes found inside the chlorite flakes. The green chloritic mineral present in some sections of gneiss, and which exhibits maximum absorption parallel to the vibration direction of the polariser, may be intermediate between mica and chlorite; it usually has a well-marked pleochroism from yellow to green. Some of the pebbles contain abundant epidotes while others contain none. The felspars are often bent or broken. In highly crushed varieties, the rock is mylonised and the quartzes are converted into a mosaic of small grains.

Pegmatite.—Albite and quartz occur intergrown. Very little biotite and chlorite are present. As the result of crushing the flaky minerals are sometimes found as streaks.

Aplite.—These are fine-grained and equigranular, exhibiting under the microscope a typical allotriomorphic texture. It is composed mainly of albite and quartz, chlorite being in very subordinate amount. The felspars are sericitised.

Microgranite.—The minerals present are albite, quartz and biotite. Grains of magnetite are scattered throughout the sections. The texture is microgranular.

Granodiorite.—Albite occurs in long crystals, which are invariably bent or broken; when broken, chlorite fills the interspaces between the fragments. No biotite was noticed, as it has probably all been converted into chlorite. The chloritic patches contain grains of leucoxene. The pebble is highly crushed and traces of a diablastic texture are present. It is comparable to the rock noticed by the writer on the slopes of the hill north of the 4th milestone between Birur and Lingadhalli, and of which a brief description has been given earlier. The only difference is in the occurrence of biotite in the rock and its absence in the pebble.

Granophyre.—The pebbles are composed chiefly of big plagioclase felspars which show a very characteristic intergrowth texture along the borders (Plate XXIV, Fig. 3). The rock may be described as a plagioclase granophyre or markfieldite.

Amphibolite.—This is a very coarse rock composed almost entirely of a pale hornblende. Grains of calcite and iron ore are present.

Hornblende schist.—This is a coarse diorite-like rock consisting of plagioclase and pale hornblende. This seems to resemble the recrystallised rock described as interaction diorite from near Karehalli. Biotite occurs in small quantities. Ilmenite altering to leucoxene is common. Chlorite and zoisite occur as secondary minerals.

Serpentine.—The pebble was obtained about a mile west of the Sivapur Railway Station. It is composed wholly of serpentine with abundant magnetite dust. The original nature of the rock is not clear. It is traversed by veins of calcite. The specific gravity of the pebble is 2·70.

Quartz felspar porphyry.—Albite occurs as phenocrysts in a very finegrained and compact matrix (Plate XXIV, Fig. 4). Orthoclase phenocrysts are rare. Areas of coarse quartz mosaics represent crushed phenocrysts of quartz.

Felsite.—This is a very fine-grained crystalline rock. Albite occurs as phenocrysts, many of which are broken due to pressure. These crystals are almost always bordered by a zone of chlorite which has well marked pleochroism from yellow to green. Quartz sometimes occurs in granular mosaics. The compact matrix contains abundant flakes of chlorite, and is peppered with numerous minute magnetite crystals. Acicular apatites occur as accessory minerals. This pebble strongly resembles the rock described as felsite from Galipuje (13° 27′ : 75° 47′) (P. Sampat Iyengar, 1908, p. 78), but unlike the typical rock, it contains no biotite, the chlorite and magnetite being derived from its alteration. The specific gravity of the pebble is 2·59.

Rhyolite.—The pebble is composed of a dark grey compact rock. Under the microscope it is seen to be highly crushed and sheared. The fine-grained matrix is formed of quartz and a pale chlorite. Fan-shaped aggregates of felspar occur, often in rows; the way in which they extinguish indicates that they are crushed and drawn out spherulites or sectors of spherulites. Minute grains of rutile are common as accessory. The specific gravity of the pebble is 2·69.

Keratophyre.—Some of the pebbles have a typical trachytic texture composed of numerous laths of albite. Biotite is the chief mafic mineral. A little chlorite and occasional rhombs of calcite are present. In other pebbles of this rock, more chlorite than biotite occurs, with scattered crystals of magnetite.

Albite dolerite.—These exhibit a hyalo-ophitic texture with albite laths as the principal mineral. Excepting for this type of texture, the rock seems to be allied to the keratophyres described above.

Spilite.—This is a vesicular rock with albite as the chief variety of felspar. Chlorite, biotite and muscovite (which may be paragonite), occur. There are numerous tiny grains of magnetite. A little quartz is present. There are only slight differences between this and the albite dolerites and keratophyres.

Quartzite.—The pebbles are formed of granoblastic aggregates of quartz (Plate XXIV, Fig. 5). A mosaic texture is more common, but in some varieties a sutured texture is noticed. Some of the bigger grains of quartz exhibit peripheral granulation. The cementing material has gone into chlorite and this mineral often outlines the grains of quartz. Biotite and muscovite sometimes occur in small quantities. Cubes of pyrites and grains of magnetite, tourmaline and rutile are occasionally present.

Quartz schist.—These are rocks which contain no felspar and are formed essentially of quartz. There is a banded texture, layers of quartz being separated by streaks composed of biotite, chlorite, muscovite and epidote. Rhombs of a carbonate occur, and since they are gone into brown iron ore, the original mineral may have been siderite.

Magnetite quartzite.—Several pebbles of banded quartzite have been collected by the writer from the conglomerate area, but they are not the typical highly ferruginous banded quartzites which outcrop strongly on the Bababudans or on Dodbetta, near Lingadhalli. They are essentially composed of quartz mosaics but with a distinct banding which is accentuated by the segregation of tiny crystals of magnetite (Plate XXV, Fig. 1). These seem to be a sort of intermediate stage between the pure quartzites and the banded ferruginous quartzites. Tiny flakes of chlorite and small grains of tourmaline have been noticed in some sections. The specific gravity of one of the pebbles was found to be 2·70.

Phyllite.—The writer has noticed pebbles of phyllite on the hills west of Baliganur, which clink like slates when struck by a hammer. They are highly fissile and are composed mainly of sericite and chlorite.

Limestone.—The pebbles are formed chiefly of calcite (Plate XXV, Fig. 2). The rock sometimes possesses a blastoporphyritic texture, the porphyroblasts of calcite often exhibiting a diablastic intergrowth with quartz. A green chlorite, pleochroic in shades of yellow and green is common. Quartz occurs in minute granular aggregates. Grains of ilmenite and magnetite are sometimes abundant. Clusters of tiny yellow rutile crystals are present; these are often intimately associated with the ilmenite grains. This combination is somewhat similar to what has been observed by Dr. Fermor in the mica schists of Balaghat, which according to him are metamorphosed sediments (L. L. Fermor, 1909, pp 313-14).

7. *The Matrix.*

The matrix of the Kaldurga conglomerates is not quite uniform in composition throughout the area. As has already been indicated, it grades from chlorite and mica-chlorite schists, through gritty chlorite and mica schists, to quartz schists. In the upper division, the matrix may in some places be designated as an arkose because of the presence of grains of albite. Some of the grits which contain a good deal of chloritic and micaceous minerals could be described as greywackes. Ferruginous material is abundant in some cases. Calcite occurs in grains and in irregular patches. Minute rutiles are fairly common, especially when the matrix contains plenty of chlorite and mica. Muscovite is very often present (Plate XXV, Fig. 3).

The boundary between the pebbles and the matrix is usually well marked. The pebbles when removed, leave smooth-walled depressions which are coated with a layer of chlorite. The pebbles and matrix can also be distinguished under the microscope by their mineralogical and textural differences (Plate XXV, Fig. 4) ; the boundary is often knife sharp and is sometimes indicated by a thin line of chlorite (Plate XXV, Fig. 5). It is only in the upper division where sometimes a gneissic pebble is in contact with matrix composed of a felspathic grit, that the differences are not quite appreciable. It is such sections that must have led several of the previous observers to consider the conglomerates as autoclastic, and to state that there was no difference between the pebbles and the matrix.

8. *Mode of Origin.*

The question of the probable mode of origin of the conglomerates of Mysore has had an interesting history. Till the year 1908, the conglomerates were considered to be sedimentary (R. Bruce Foote, 1882, p. 195 ; 1900, pp. 29-31 ; V. S. Sambasiva Iyer, 1899, pp. 89-90, 97 ; 1901, pp. 121-23. P. Sampat Iyengar, 1905, pp. 73-74 ; H. K. Slater, 1903, pp. 126-28 ; 1905, p. 20 ; 1906, pp. 3-7 ; W. F. Smeeth, 1899, pp. 162, 165 ; 1902, p. 18 ; 1904, pp. 20-21 ; E. W. Wetherell, 1903, p. 92 ; 1904, p. 24). Later, Dr. W. F. Smeeth, the Director of Geology in Mysore, examined the Mallapanhalli (14° 4′ : 76° 40′) and Aimangala conglomerates of the Chitaldurg schist belt during the field season of 1909-10, and pointed out certain evidences which, according to him, were in favour of their being considered as autoclastic in character and not of the nature of true sedimentary conglomerates (W. F. Smeeth, 1910, pp. 15-18, 34-35). This idea was soon extended to all the other conglomerates of Mysore ; everyone of these was shown to fit in with the 'autoclastic' theory and the original suggestion of some of these being sedimentary came to be completely abandoned (B. Balaji Rao, 1913, pp. 139-40 ; 1928, pp. 88-89 ;

B. Jayaram, 1910, pp. 180-81 ; 1916, pp. 93-94 ; 1922*a*, pp. 84-86 ; 1922*b*, pp. 54, 57-58, 64 ; B. Rama Rao, 1924, pp. 179-81 ; P. Sampat Iyengar, 1908, p. 72 ; 1912, pp. 54-56 ; 1916, p. 134 ; 1917, pp. 106-16 ; A. M. Sen, 1916, pp. 150-53 ; H. K. Slater, 1912, pp. 26-29 ; W. F. Smeeth, 1910, pp. 12-18, 25, 34 ; 1912, p. 38). So thoroughly did the officers of the Mysore Geological Department support the views of their chief, that Smeeth says in one of his annual reports, "I appear to have raised quite a hornet's nest of the latter type (autoclastic conglomerates) and I long for some one to find a simple satisfactory sedimentary conglomerate with nicely rolled, water-worn pebbles" (W. F. Smeeth, 1912, p. 38).

It would not be out of place to consider briefly the reasons which led Dr. Smeeth to attribute to the conglomerates of Mallapanhalli and Aimangala, an autoclastic origin, especially because of the very great influence his views have undoubtedly had on all later works in the Mysore State. Referring to Mallapanhalli, he says, "I was struck by the possibility that the matrix might prove to be of similar material to the pebbles or boulders, though more crushed, particularly in the case of the grey trap pebbles." In some places, he thought that there was a clear transition from uncrushed boulder to crushed matrix in one and the same material and in such cases he was of the opinion that "there can be no doubt that the whole mass was originally grey trap which, after developing spheroidal structure, has been somewhat crushed and sheared leaving uncrushed spheroids in a crushed schistose matrix". This is quite a valid argument and is one of the main reasons for considering any conglomerate as autoclastic in origin. But in Mallapanhalli, pebbles of vein quartz and limestone were also found, and no resemblance between these and the matrix could possibly be discovered. Smeeth got over this by regarding the quartz and limestone pebbles as "xenoliths or rounded eyes of secondary minerals".

This difficulty was more pronounced in the case of the Aimangala conglomerates, since these rocks are largely composed of pebbles of such varied character as granite, quartzite, hornblendic rocks and banded ferruginous quartzite, set in a dark grey and somewhat gritty matrix with some chlorite and mica. In referring to this conglomerate, Smeeth says, "it certainly has the appearance of a genuine sedimentary conglomerate from the varied and rounded character of the pebbles and the contrast which many of them afford to the matrix, and for a time, I allowed it to pass as such, although it was difficult to account for its position in the midst of a wide expanse of chlorite schists. Since then, a careful examination of the specimens...... has led me to entirely alter my view. I find that a large number of the pebbles are indistinguishable under the microscope from typical portions of the matrix, both consisting of rounded to subangular grains of quartz in a matrix of clayey material more or less impregnated with brown oxide of iron ....I now regard the whole occurrence as being of granite origin and intrusive with the chlorite schists, the granite pebbles being lumps of harder material isolated and rounded by shearing and crushing, and the lumps of hornblendic rock and ferruginous quartzite being xenoliths in intrusive granite" (W. F. Smeeth, 1910, pp. 34, 35).

Similar arguments were advanced to explain the nature of the conglomerates elsewhere. In the Hodigere conglomerates occurring in the Shimoga schist belt, the pebbles were considered by Slater to be "the result of pressure on intrusive bands or sills of quartzite and granite", though on the same page he says that "the granite pebbles are of the Honnali granite variety and shew practically no crushing in the microsections" (H. K. Slater, 1912, p. 28). According to Jayaram, the pebbles in the Gangur conglomerates are "sheared and drawn out phenocrysts and autoliths in the rock" (B. Jayaram, 1922*b*, p. 55).

As has been mentioned earlier, it was Sampat Iyengar who examined the Kaldurga conglomerates in any detail. He was definitely of the opinion that the conglomerates were autoclastic. According to him, mineralogically there was not much difference to be noticed between the gritty mica chlorite schists and the granite matrix of the conglomerate. The brownish gritty mica chlorite schist and the dark green chlorite schist were considered by him to be the crushed and altered phases of the Champion gneiss, into which tongues of the Tarikere gneissic granite have intruded and got converted along shear zones into conglomeratic masses.

After a fairly intensive study of these conglomerates and grits, both in the field and in the laboratory, the writer has come to the conclusion that the autoclastic theory cannot be applied to explain the origin of these rocks. It is proposed to bring together in the following paragraphs, certain data, some of which have already been briefly touched upon in the preceding pages; these facts cannot adequately be explained by the autoclastic theory but, on the other hand, they suggest a sedimentary origin to these rocks.

Shape and rounding of pebbles.—Almost every observer who has visited the Kaldurga area has remarked on the shapes of the pebbles and the degree of rounding which they exhibit (Plate XXIII). In fact, these were practically the main reasons which led the earlier geologists to consider these conglomerates as sedimentary.

Sharp boundary between pebbles and matrix.—From slightly weathered specimens the pebbles can be easily dislodged, when they leave smooth depressions. The boundaries of the pebbles are usually clean and marked by films of chlorite. This is very well seen even under the microscope (Plate XXV, Figs. 4 and 5).

Varied assemblage of pebbles.—From the description which has already been given in this paper, it will be seen that the conglomerates contain a very varied assemblage of pebbles. In small hand specimens, there are sometimes as many as six different petrographic types occurring as pebbles. This has been explained by the supporters of the autoclastic theory as due to the crushing of a complex containing different rocks as xenoliths. While prepared to admit that some of these rock types can occur as xenoliths in granite, the writer fails to see how so many different kinds of pebbles could be found aggregated within the space of a few square inches. This implies the breaking up of the xenoliths and a bodily migration of the pebbles caused by thorough churning of the rock during or after the formation of the pebbles, assumptions which are extremely improbable.

Difference between pebbles and matrix.—There are well-marked differences between the pebbles and matrix. This is naturally to be expected when there are so many different types of rock represented among the pebbles. This difference is not easily noticed when pebbles of granite or gneiss are found in the upper division or when pebbles of schist occur in the lower division. But identity between pebbles and matrix cannot be proved by selecting one out of the several types of pebbles occurring in the conglomerate and showing its resemblance to the matrix. To consider all the other varieties of pebbles which do not conform with the matrix, as xenoliths or segregations is, also, in the writer's opinion, not quite a valid argument. According to Slater, the matrix is a crushed quartz porphyry (H. K. Slater, 1906, p. 4). Sampat Iyengar thought it was the Tarikere gneissic granite (Peninsular gneiss) (1917, p. 113), but later referred it to the Champion gneiss (1920, pp. 7, 9). The writer finds that the matrix is not quite uniform, though there is a general resemblance. The matrix of the lower division is somewhat more basic because of its probable derivation from the spilites and epidiorites; this grades upwards into a more acidic type with plenty of quartz and grains of felspar. Chlorite forms one of the chief minerals in the matrix of these conglomerates.

Distribution of rutile.—A very suggestive difference between the pebbles and the matrix is seen in the distribution of rutile. Yellow grains of this mineral are abundant in the matrix but are decidedly of sporadic occurrence in most of the pebbles, except in those belonging to spilites and keratophyres. Rutile is more prevalent in the lower division than in the upper, and is authigenic.

Veins in pebbles.—Veins occurring in the pebbles stop abruptly at their boundary with the matrix. This is very well seen both in the field as well as in microsections. It may be mentioned here, that one of the arguments advanced by Wagner for considering certain conglomerates of South Africa as non-sedimentary in origin, is that the original black or brownish-red banding of the chert can sometimes be traced across the intervening matrix from one "pebble" to the other (P. A. Wagner, 1927, p. 55). The matrix of the Kaldurga conglomerate is often schistose as the result of pressure, but there is no parallelism or relationship between this schistosity and the banding of the quartzite or gneiss pebbles; they are arranged anyhow.

Alternation of pebbly and non-pebbly bands.—Almost throughout the Kaldurga area, pebbly layers are seen to alternate with fine-grained non-pebbly layers. This character imparts a banded nature to the outcrops. The non-pebbly layers are somewhat deeper in colour than the pebbly bands. Slater observed this feature but did not offer any explanation (H. K. Slater, 1906, p. 3). Sampat Iyengar in attempting to explain it by invoking purely igneous phenomena, has suggested that this banding is the "result of an initial segregation into layers of normal, acid and basic portions in the gneissic granite" (P. Sampat Iyengar, 1917, p. 108)—a very difficult explanation. This banding can be satisfactorily accounted for by the sedimentary theory, as it is a phenomenon met with in many sedimentary conglomerates. The pebbles are not supplied uniformly, and at certain stages only finer material was deposited. That there is no other difference between these bands, could be seen under the microscope, for the material composing the fine-grained bands is identical with the matrix cementing the pebbles in the conglomeratic bands.

Graded bedding, Current bedding.—As has been mentioned earlier, the pebbly grits exhibit very good grading on the hills about a mile west of Baliganur. Layers of rocks varying in thickness from 9″ to 15″ occur here, and each layer grades from coarse pebbles at the bottom to fine grit at the top. In other outcrops of these grits, a crude cross bedding also showing grading of the grains is sometimes seen.

Pebbles flattened at right angles to bedding planes.—The pebbles have generally been crushed and flattened. In some cases, the pressure has acted almost parallel to the bedding planes and hence the pebbles appear to stand vertically to the plane of bedding. This can be observed very well on the hills west of Baliganur.

Absence of pebbles of age posterior to conglomerates.—Hill, who was one of the earlier British geologists who recognised the occurrence of crush-conglomerates, states, "in doubtful cases, the only safe test of original deposition is the presence of foreign fragments sufficiently large to escape being confounded with the materials which form the matrix. Similarly, the most satisfactory proof of deformational structure is the inclusion of igneous boulders derived from rocks posterior in age to the matrix" (J. B. Hill, 1901, p. 327). The only rocks which are distinctly of later age in this area are the granites of the Tarikere valley and those occurring near Kadur and Birur. These granites contain orthoclase and microcline and it is significant that the granite pebbles occurring in the Kaldurga conglomerates do not bear these felspars. It is interesting to note that the granite pebbles occurring in the conglomerates of Lomagundi in Southern Rhodesia, differ precisely in the same way from the intrusive granite of the area (Mennel, 1910, p. 359).

It has already been mentioned that pebbles of banded ferruginous quartzites occur in the conglomerates. Examination of parts of the Shimoga schist belt has convinced the writer, that the banded quartzites were not deposited at one particular time, but that there were varying intervals between the deposition of the several bands. In some cases they are practically pure quartzites showing faint traces of banding. Near Allampur, north of Chikmagalur, the quartzites are current bedded, and this character would, perhaps, have escaped observation, if the successive bands were not demarcated by thin ferruginous layers. Some banded quartzites contain more iron and these grade into the typical ferruginous quartzites with a high percentage of iron. In the explanation of the structure of the area offered by the writer, the banded ferruginous quartzites are seen to be distinctly older than the conglomerates, and hence their occurrence as pebbles is naturally to be expected.

The presence of pebbles of vein quartz and the runs of vein quartz occurring in the area, have caused some confusion, but it must be recognised that these are not all of the same age. The veins connected with the intrusion of the later granites are, of course, later than the conglomerates, and they do not show any signs of pebble formation.

Evidence of the grits.—The assemblage of varied types of rocks occurring as pebbles in hand specimens of the conglomerates has been already mentioned. This phenomenon is more prominently noticed in some of the grits. The small fragments making up the grits are often of different petrographic types. In sections cut from one hand specimen, the writer has recognised fragments of granite, pegmatite, micropegmatite, keratophyre, quartz grains and quartzites of different grain sizes. Several of these are often seen within the compass of a single microsection. The boundaries of these fragments are quite distinct. It would be extremely difficult to explain this intimate mixture of various types of rock by considering that they are crushed xenoliths. There is the interesting possibility that these grits might represent metamorphosed volcanic tuffs, but till more definite proof of this is obtained, the writer would like to suggest that such a collection of different types of fragments could not have been caused by the action of mere pressure alone. Deposition under water is indicated.

The evidences of pressure on the conglomerates are many, and these are mainly responsible for their having been considered as examples of crush conglomerates. The rock has often developed a schistose structure and the pebbles have been rolled out, elongated or converted into lenticular shapes; sometimes they have been flattened. The effects of pressure are well seen in microsections. Quartz grains usually exhibit undulose extinction, and larger grains frequently show peripheral granulation. Twinning lamellations have been enhanced in plagioclase, and are often broken and faulted.

The writer is not unaware of the possibility that in certain localities in the Mysore State, the effects of pressure and igneous intrusion have been such as to form brecciation of rocks leading to the development of autoclastic conglomerates similar to those described from the Isle of Man (G. W. Lamplugh, 1903, pp. 55-58) and Spitzbergen (G. W. Tyrrell, 1924, pp. 463-64). The evidences put forward in this paper are confined purely to the region under investigation and point definitely to the conclusion that the Kaldurga conglomerates have had a sedimentary origin.

9. *Other Ancient Conglomerates in India.*

A brief mention may be made here of similar ancient conglomerates recorded from other parts of India. Bruce Foote who considered all the Mysore conglomerates as sedimentary, was of the same opinion regarding those found in the Lower Transitions of the Bellary District, Madras (R. Bruce Foote, 1896, pp. 80, 87, 105-107, 140). Typical crush conglomerates have been described by Hayden from the Lower Haimantas in the valley of the Lipak River (H. Hayden, 1904, pp. 11-12). Maclaren has considered as sedimentary those conglomerates occurring in the Tungabhadra region where pebbles and boulders of granite, apatite, quartz-porphyry, quartzite and banded jasperoid quartz occur embedded in a schistose felspathic matrix containing chlorite (J. M. Maclaren, 1906, p. 108). Underlying the manganese ore band at Ukua and Balaghat, Fermor noticed a rock which appeared to be an ordinary mica-gneiss. Since there were pebbles of various materials like white quartz, granite and gneiss, set in a matrix which resembles the composition of a micaceous gneiss, he considered this rock as a metamorphosed conglomeratic grit, similar to those described by Cunningham Craig from the Loch Lomond district in Scotland (L. L. Fermor, 1909, p. 311). At Rewasa, in Rajputana, sedimentary conglomerates of the Aravalli system contain pebbles of white quartz, pale and dark grey quartzite, white grit and mica schist; these are found in a schistose matrix of biotite and chlorite with octahedra of magnetite (A. M. Heron, 1917, p. 17). In north Singbhum, interbedded with phyllitic slates, there are conglomerates which contain pebbles of quartz, banded and normal quartzite, chlorite schist, tourmaline-quartz rock and granite, set in a sericite-quartz schist matrix. The rocks are highly sheared but according to Dr. Dunn they are not autoclastic but sedimentary rocks deposited during periods of intervolcanic erosion (J. A. Dunn, 1929, p. 35). Recently a detailed study of some conglomerates of Dharwar age from Chota Nagpur and Jubbulpore has been made by Dr. Krishnan. The pebbles are of quartzite, micaceous quartz-schist, translucent vitreous quartz, fine-grained biotite schist, phyllite, granite and occasionally tourmaline-quartz rock. The groundmass contains chlorite, sericitic matter, some biotite and magnetite. These conglomerates are considered by Krishnan to be of sedimentary origin, though locally the crushing and shearing have been so intense as to impose autoclastic characters (M. S. Krishnan, 1934, pp. 455-63). A similar conclusion has been arrived at by Ray regarding some of the conglomerates found in the Jubbulpore District (S. K. Ray, 1932, pp. 113-18).

10. *Summary.*

A very well-developed bed of conglomerate outcrops in and around Kaldurga in the Kadur District. The official opinion of the Mysore Geological Department regarding these conglomerates is, that they are of autoclastic origin. As the result of a detailed study of the pebbles and the matrix, the writer has come to the conclusion that the conglomerates are not autoclastic, but that they are sedimentary formed. The intense crushing and shearing to which they have been later subjected, have tended to obscure their original nature. A very varied assemblage of pebbles has been discovered by the writer. The pebbles are composed of granite, gneiss, pegmatite, aplite, microgranite, granodiorite, granophyre, amphibolite, hornblende schist, serpentine, quartz felspar porphyry, felsite, rhyolite, keratophyre, albite dolerite, spilite, quartzites, quartz schist, magnetite quartzite, phyllite and limestone. The shape of the pebbles, the mineralogical and textural differences between the pebbles and the matrix, and absence of pebbles belonging to rocks posterior in age to the matrix of the conglomerates are some of the reasons adduced in favour of a sedimentary origin for these conglomerates.

11. *Acknowledgments.*

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Handspecimen of conglomerate containing eight different kinds of pebbles. 1. Granite. 2. Gneiss. 3. Microgranite. 4. Pegmatite. 5. Quartz-Felspar Porphyry. 6. Spilite. 7. Quartz Schist. 8. Quartzite.

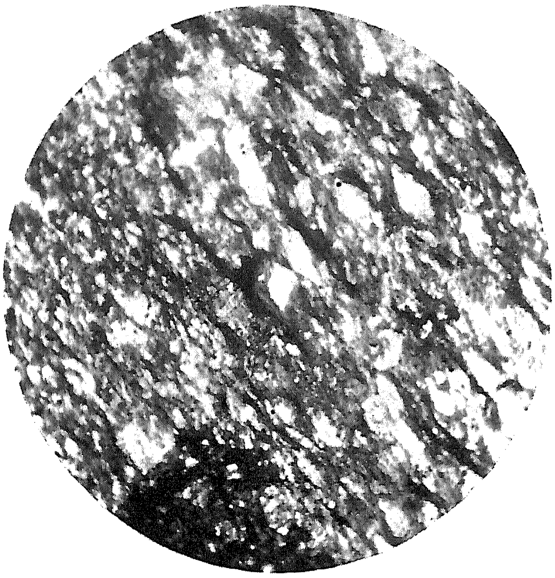

FIG. 1.

FIG. 2.

FIG. 3.

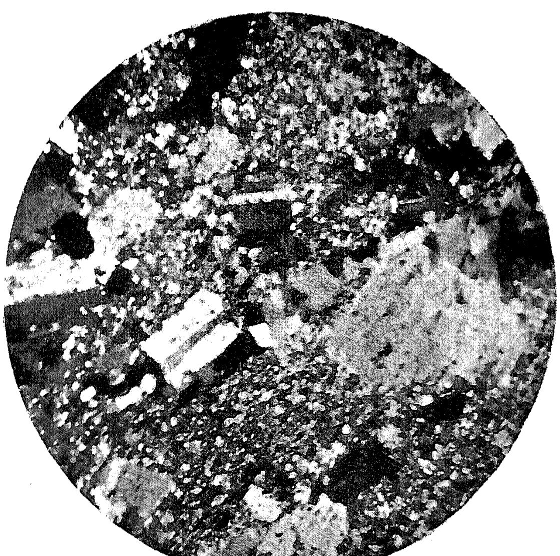

FIG. 4.

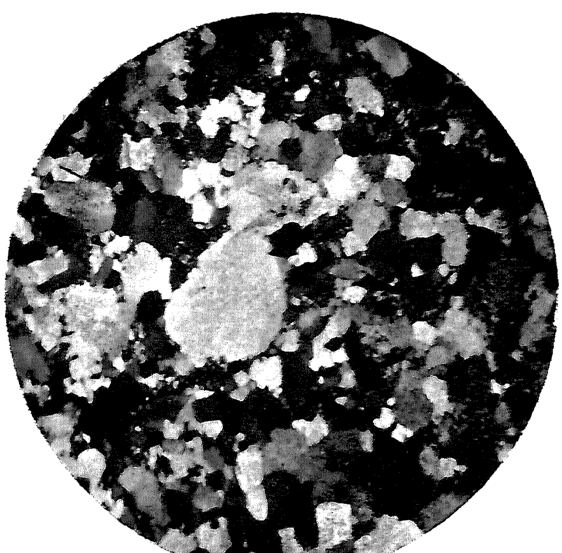

FIG. 5.

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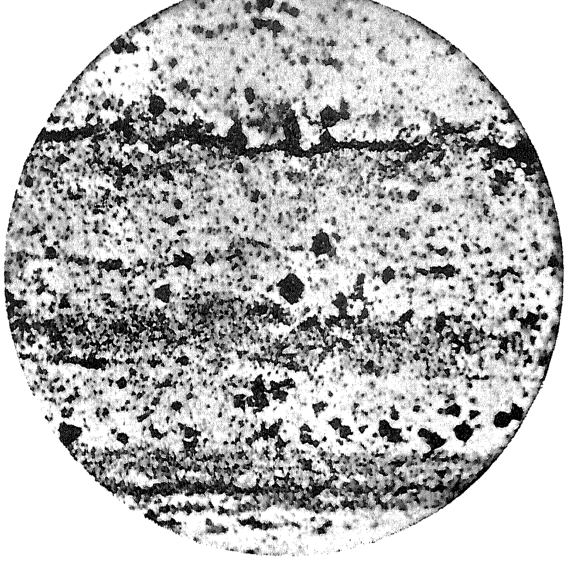

FIG. 1.

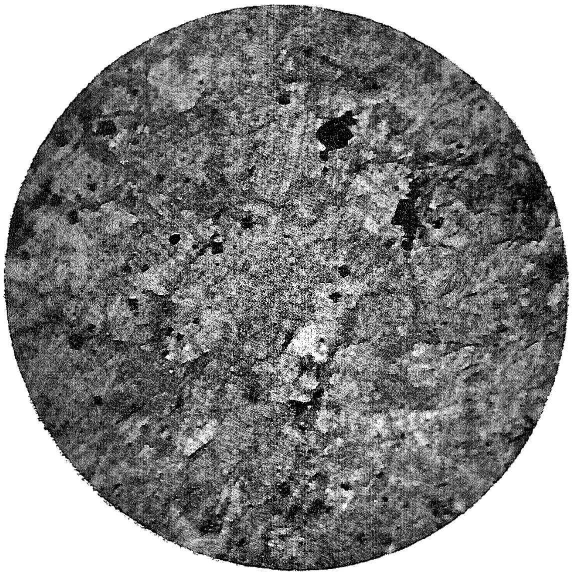

FIG. 2.

FIG. 3.

FIG. 4.

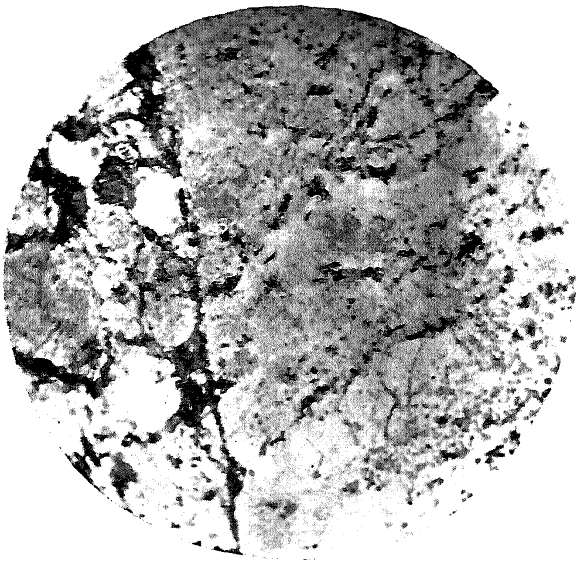

FIG. 5.

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EXPLANATION OF PLATES.

Plate XXIII.

Specimen of conglomerate containing several types of pebbles, such as granite, gneiss, micro-granite, pegmatite, quartz felspar porphyry, spilite, quartz schist and quartzites. Many of the pebbles are rounded. × ¾ natural size.

Plate XXIV.

Fig. 1.—Ordinary light. Sheared chloritic grit. The colourless areas are formed of quartz and the dark portions, mostly of chlorite. × 22.

Fig. 2.—Ordinary light. Grit, 1 mile W. of Baliganur. A fragment of somewhat altered spilite is present. The colourless fragments are of vein quartz and quartzite. × 22.

Fig. 3.—Crossed nicols. Section of granophyre pebble. A crystal of plagioclase is surrounded by the characteristic micrographic intergrowth. × 30.

Fig. 4.—Crossed nicols. Section of pebble of quartz felspar porphyry. The felspars are almost all of them albites. The groundmass is minutely crystalline. Quartz occurs in patches with a mosaic texture. × 22.

Fig. 5.—Crossed nicols. Section of quartzite pebble with typical mosaic texture. × 22.

Plate XXV.

Fig. 1.—Ordinary light. Section of magnetite quartzite pebble. It is not so ferruginous as the typical hematite and magnetite quartzites of the Bababudans. The banding is emphasised by the parallel arrangement of the minute octahedra of magnetite. × 22.

Fig. 2.—Ordinary light. Section of limestone pebble. Chlorite and magnetite are associated. × 22.

Fig. 3.—Ordinary light. A portion of the matrix. The abundant colourless mineral is muscovite, which is associated with chlorite. × 22.

Fig. 4.—Crossed nicols. Illustrates the sharp contact of a granite pebble with the fine-grained quartzose matrix. × 22.

Fig. 5.—Ordinary light. The dark thin line separating the pebble from the matrix is composed of chlorite. × 22.