Geochronological aspects of stabilization of continental precambrian platforms

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Geochronological Aspects of Stabilization of Continental Precambrian Platforms

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ABSTRACT

Five megacycles have been recognized in the history of evolution of crustal structure. The rearrangement in continental architectonics, stabilization of crustal platforms, and formation of folded mobile belts are associated with the above mentioned megacycles. The present and other data are indicative of the transition of kratogenized Precambrian areas into areas of mobile geosynclinal zones which took place in several regions. This evidence points to the fact that at the base of the Phanerozoic folded belts Precambrian formations exist. This rules out any conclusion that the continental crust of the platforms expands at the expense of the oceanic crust by consecutive addition of new mineralized structural stages.

Progress in the methods of determining absolute age of minerals and rocks has been a powerful means for studying Precambrian formations. By now vast territories of Precambrian formations on all continents have been covered by geochronological investigations, which makes it possible to follow the comparative history of the Precambrian platform stabilization.

In the general scheme of crustal development on all continents, in accordance with the geochronological scale accepted for the Soviet Union, five megacycles of rearrangement of continental architectonics, stabilization of platforms and origin of new geosynclinal mobile folded zones, may be distinguished; and these are associated with new structural stages in the formation of the crust.

Fig. 1 shows protoplatforms of the second Precambrian megacycle representing the oldest crustal blocks that have retained their stabilized state since the age of 2700 m.y.; they are composed of the most ancient folded structures dated at 3500 m.y. Platforms of the third Precambrian megacycle, retaining their stabilized state since the age of 2000 m.y. are also shown on the map; these consist of crustal structural stages which had been formed during the first and second Precambrian megacycles dated at 2000 to 3500 m.y.

The oldest protoplatforms which escaped rearrangement and granitization of the subsequent megacycles have been recognized on the African, European, and Australian continents.

On the European continent there is: the Kola peninsula Saami protoplatform consisting of Katarcheic formations dated at 3500 m.y., and the Dnieper Konski

protoplatform of the Ukrainian shield composed of folded structural stages which were formed during the Konski and Aulski cycles and with an age of about 2700 to 3500 m.y.

The Konski series is represented by sedimentary-volcanogenic formations that may be classified into two series; they include acid, basic, and ultrabasic volcanogenic formations, sedimentary argillaceous, sandy, and ferruginous-siliceous deposits which are preserved as metamorphic schists and hornfels.

On the African continent there is: the Swaziland or South African platform dated at 3500 m.y., consisting of the Swaziland, Sebakwian, Bulawayan, and Shamwaian formations; the Nile-North Congo or Central African platform made up of the western Nile and Nyanzian formations; and the Sierra Leone or West African formation composed of the Kambuian series. The Swaziland system with an age up to 3400 m.y. (deduced from lead isotopes) consists of folded sedimentary-volcanogenic formations which fall into three series. These are: the Modes series composed of conglomerates, quartzites and shales; the Fihtrian series consisting of greywackes, shales and tuffs; and the Onerwacht series formed of volcanogenic complexes, serpentinites, and ultrabasites.

The Australian continent: On the territory of the Pilbara and Kalgoorlie provinces the central nucleus of the oldest Precambrian formations is found; this is composed of the Pilbara rocks dated at 3500 m.y., and the gneiss-granites of the Yilgarn block with an age of 2700 to 2900 m.y.

The presence of geological formations of the lowest structural stages of the crust up to 3000 m.y. old has also been established on the North American continent and on the Indian peninsula.

Considering these blocks which had become stabilized since the age of 2700 m.y., with the lowest oldest structural stages of the crust preserved, one can see that they consist of geosynclinal folded formations comprising a variety of sedimentary–volcanogenic formations.

There is no doubt that the most ancient structural stages of the crust were developed over greater surface areas, but were then reworked by subsequent processes at the base of younger structural stages.

Fig. 1 shows the vast territories occupied by platforms that had stabilized by the end of the second Precambrian megacycle (2000 m.y.). These platforms are chiefly composed of mineralized folded formations of the structural stages that had been formed during the second Precambrian megacycle, including folded blocks of the first Precambrian megacycle.

In North America two platforms are distinguished: those of the Yellowknife and Superior provinces.

On the South American continent the following blocks are found: in the Guyana shield, the block composed of the Imitaka complex dated at 2800 m.y.; in Brazil, the Minas Geraes, the block consisting of the Vacao complex.

On the African continent the following platforms consisting of formations older than 2000 m.y. are recognized: the Sierra Leone and Birimian platforms, in West Africa; the Kasai-Nile platform, in North Congo; the Tanzania platform, in Central Africa; and the Rhodesian and Swaziland platforms, in South Africa.

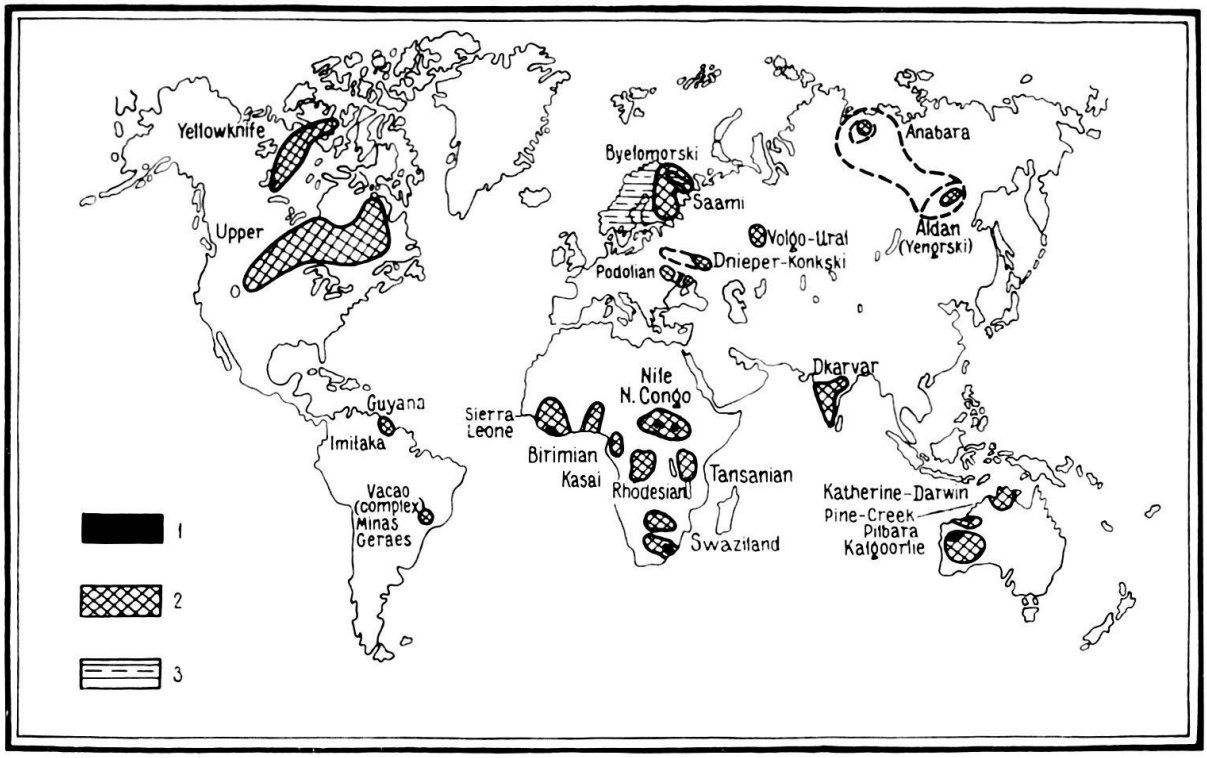

Fig. 1. Platforms older than 2000 m.y. stabilized by the end of Precambrian II and I.

1-Precambrian I, Protoplatforms older than 2700 (2700–3500) m.y.; 2-Platforms older than 2000 m.y. stabilized by the end of Precambrian II; 3-Precambrian II reworked by later foldings of Precambrian III.

On the Swaziland platform in South Africa younger platform formations of the Precambrian are observed overlying the folded structures. These platforms had been fringed by folded belts of Precambrian III with an age of 2000— 1650 m.y.: the Kibara-Tora-Buganda, the Ubendian-Rusisian, the Tumbide, the Limpopo or Messina, the Dahomey, etc.

In India, the Dharvar platform was formed; this is composed of formations dated at 2000 to 2700 m.y. and consists in general of the Dharvar system of rocks whose age has been estimated at 2600 to 2300 m.y.

In Eastern Europe, platforms were also formed consisting of the Precambrian II and older formations: the Byelomorski platform made up of the Byelomorski and older folded structures occupying the eastern part of the Baltic shield; the Voronezh and Volgo-Ural blocks on the Russian platform, composed of the Stoylinski, Sergievski, Trosnyanski, and other rock complexes with an age between 2000 and 2400 m.y., the Dnieper-Konski, Near Azov, and Podolsk platforms consisting of formations 2000 to 3500 m.y. old, occupying the greatest part of the Ukrainian shield.

In Eastern Siberia the Aldan-Yengrski and Anabara platforms appeared.

In Australia the Pilbara, Kalgoorlie, and Katherine-Darwin platforms were formed, composed of the Kalgoorlie system formations dated at 2700 and 2500 m.y., and of the Bruce group with an age of 2200–2000 m.y., etc.

These platforms, fairly well developed on all continents, were separated by folded mobile belts of the third Precambrian megacycle during the period of time from 2000 to 1600 m.y. and must have lain at the base of the younger structural layers of the crust.

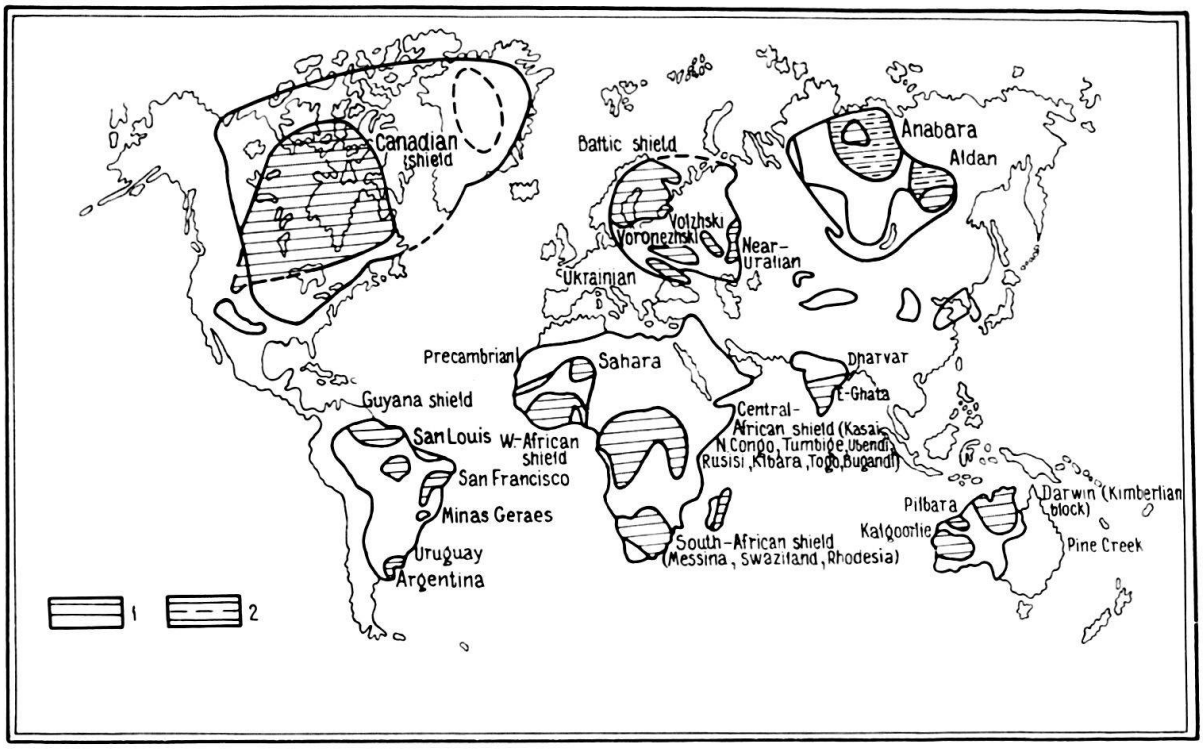

Fig. 2. Platforms older than 1700 m.y. stabilized by the end of Precambrian III.

1-Platforms older than 1700 m.y. stabilized by the end of Precambrian III; 2-Platforms older than 1700 m.y. overlain by undisturbed deposits of Precambrian IV dated at 1500 m.y.

In the geological formations developed during Precambrian II faunal remnants are found, such as on Kola Peninsula in the Imandri-Varguza suit dated at 2140 to 2280 m.y., and in South Africa.

Fig. 2 shows platforms which existed during the fourth Precambrian megacycle, were preserved in stabilized state since 1700 (1650) m.y., and consist of folded mineralized structural stages of the crust in the first, second, and third Precambrian megacycles.

In North America, the Canadian shield, comprising formations of the following provinces, evolved: the Churchill, Bear, Southern with an age of 1700 to 2000 m.y., and the Yellowknife and Superior provinces, 2000 to 2700 m.y. old.

In Eastern Europe the Baltic shield appeared, with the Ukrainian shield, the Voronezh, Volzhski and Near Uralian massifs – these platforms being composed of rocks dated at 1700 to 3500 m.y.

In Eastern Siberia since 1700 m.y. the Aldan and Anabara shields became stabilized – the platforms being mostly overlain by thick platform deposits of Precambrian age up to 1600 m.y.

On the South-American continent the following platforms evolved: the Guyana, the Tocantins-Topayos, the San Luis, the San Francisco, and the Uruguay-Argentina.

On the African continent the following features were formed: the South-African shield (Kalahari) amongst older shields of Swaziland, Rhodesia and the stabilized belt Messina, formed during Precambrian III; the Central African shield (Congo) amongst ancient platforms of Kasai, Tanzania, and North Congo and stabilized

folded belts of Precambrian III – Kibaran – Bugandian, Ubendian-Rusisian, Tumbide; the West-African shield consisting of the platforms Sierra Leone, Birimian, and the stabilized folded belts of Dahomey; and in North Africa, the Sahara platform and the Berberides.

On the Indian peninsula, south-east of the Dharvar platform, the stabilized folded belt of eastern Ghata, dated at 1650 m.y., was attached.

In Australia the following platforms became stabilized: the Kalgoorlie, Pilbara and the Katherine-Darwin block, where by the end of Precambrian III a vast territory of northeastern Australia became stabilized, consisting of the Aruptian complex dated at 1800 to 2300 m.y.

Fig. 3 shows platforms of the fifth Precambrian megacycle, older than 1200 (1100) m.y., composed of folded mineralized geological formations of the first, second, third, and fourth megacycles. They are fringed by folded belts consisting of structural stages that were formed during the fifth Precambrian megacycle.

By the end of the fourth megacycle the main areas of the Precambrian platforms in the northern hemisphere were stabilized: the North-American, East-European, and East-Siberian platforms.

The North-American platform expanded due to the attachment to the Canadian shield of the Sonora and Elsonian folded belts composed of the Apachean group, Alder group, and Masastalian group, the Keweenowan, etc. – the formations dated at 1600 — 1200 m.y.

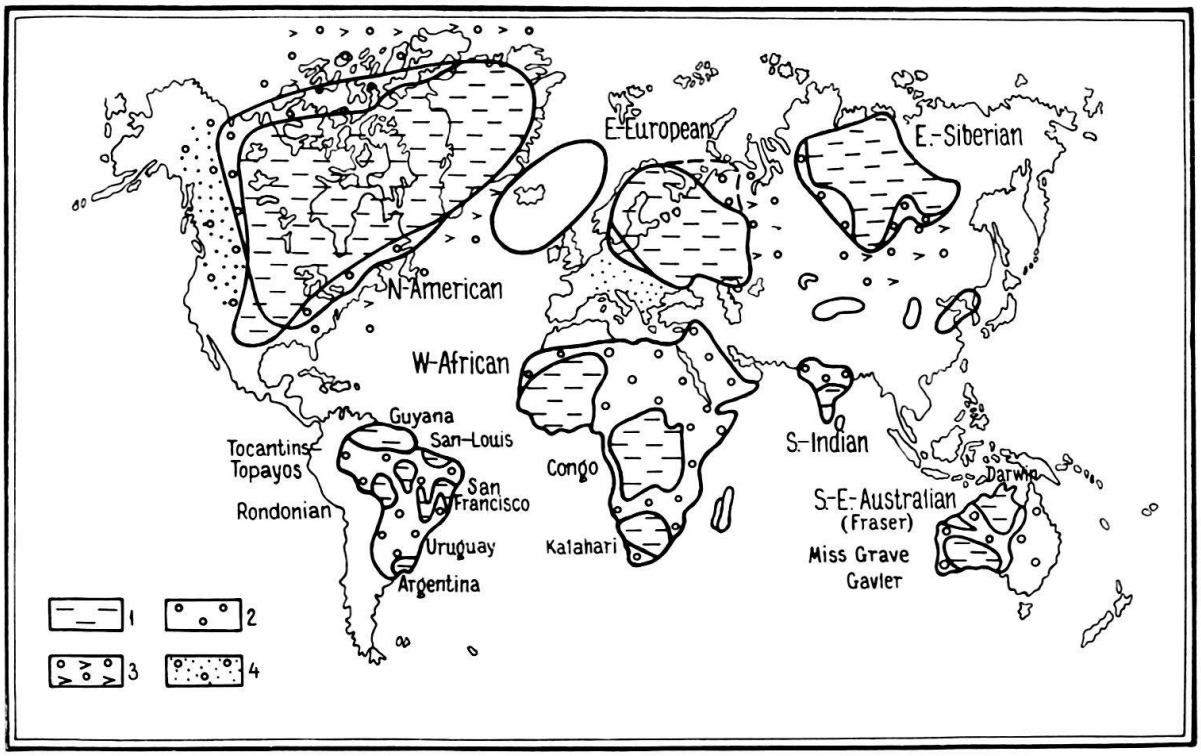

Fig. 3. Platforms older than 1200 to 1100 m.y. stabilized by the end of Precambrian IV.

1-Platforms older than 1200 m.y. stabilized by the end of Precambrian IV; 2-Folded areas of Precambrian V during the period 550–1200 m.y. Folded stages of Precambrian V dated at 550–1200 m.y. occurring within the basement 3-Paleozoic and 4-Mesocenozoic foldings.

The European platform was formed by the end of Precambrian IV in connection with the stabilization of belts of the Ovruch-Volyn folding that was common on the Russian platform between the Baltic, Voronezh, Volga, and Ukrainian shields.

Many researchers believe that the East-European platform had become generally stabilized by the end of Precambrian III, at an age of 1700 m.y.

In the southern hemisphere large platforms were formed occupying about 50% of the continental territory.

On the African continent the following platforms became stabilized: the West-African platform, the Congo platform in central Africa and the Kalahari platform in south Africa. There, further expansion of the previously formed platforms in southern, central, and western Africa took place at the expense of the folded belts Karagwe-Ankola, Burundi-Kibara, Tarquian, etc. dated at 1600–1100 m.y. that had become stabilized by the end of the fourth Precambrian megacycle.

In Australia the following platforms are distinguished: the Darwin platform (Kimberlian block) and the southeastern Australian platform, the latter one expanding at the expense of the stabilizing zones: the Fraser, Miss Grave and Gavler dated at 1500—1200 m.y.

On the South American continent by the end of Precambrian IV the Guyana, Tokantins-Topayos and Rondonian (in Western Brazil) platforms appeared, as well as the San Francisco and the Uruguay-Argentina platforms.

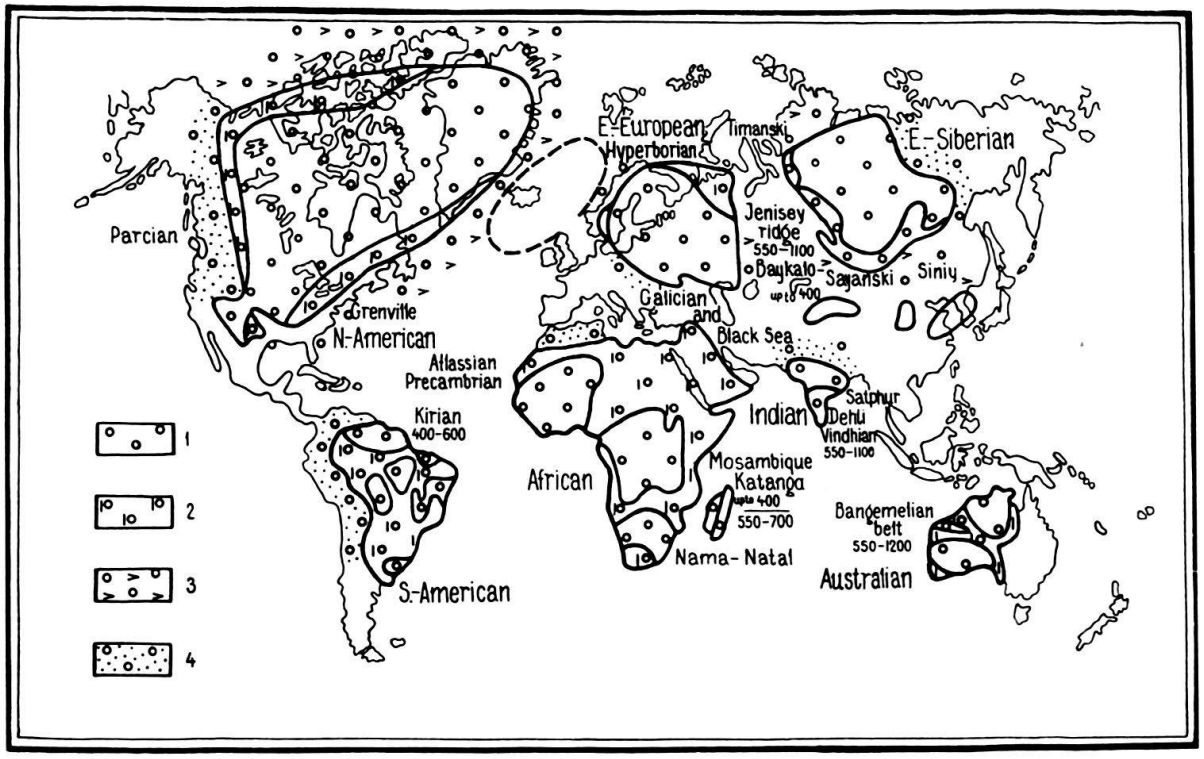

Fig. 4. Platforms older than 550 m.y. stabilized by the end of Precambrian V.

Platforms older than 500 m.y.: 1-platform areas stabilized by the age of 1200 m.y.; 2-Platform areas stabilized during Precambrian V between 550 and 1200 m.y. Folded stages of Precambrian V dated at 550–1200 m.y., occurring within the basement. 3-Paleozoic; 4-Mesocenozoic.

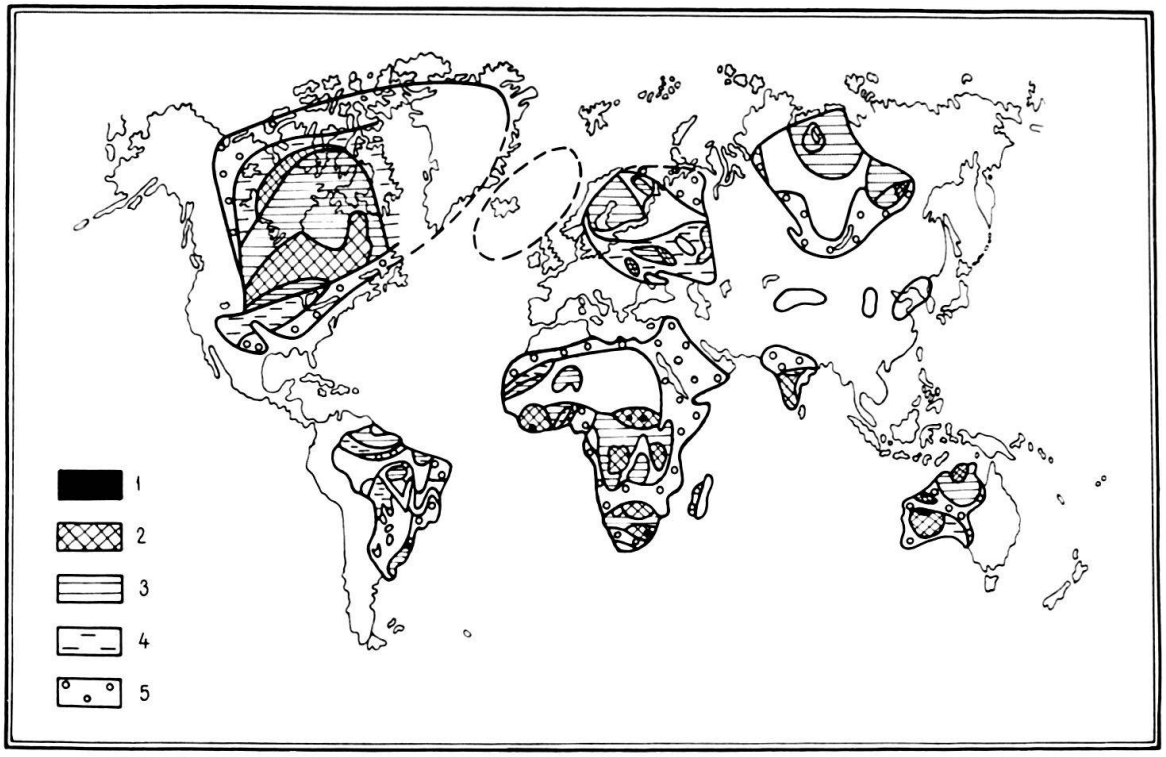

Fig. 5. Geochronological map of continental Precambrian.

1-Precambrian I 2700–3500 m.y.; 2-Precambrian II 2000–2700 m.y.; 3-Precambrian III 1700 to 2000 m.y.; 4-Precambrian IV 1200–1700 m.y.; 5-Precambrian V 550–1200 m.y.

Fig. 4 shows platforms of the sixth – Phanerozoic – megacycle, older than 550 m.y., composed of geological formations of all five Precambrian megacycles with ages from 550 to 3500 m.y.

In the northern hemisphere the previously formed platforms expanded at the expense of the periphery of folded belts which had been formed during Precambrian V and were partly stabilized by the end of Precambrian V.

The partially stabilized folded formations of the Parcian, Guardian, and Grenville belts became attached to the North American platform.

The East-European platform joined to the Timanski and Dalaslandski folded belts.

The East-Siberian platform includes the partly stabilized Baykal-Sayany belt and the Yenisey ridge. The East-Siberian platform is fringed to the south by the Baykal folded belt which, after the fifth Precambrian megacycle, went on developing in the Caledonian cycle.

The East European platform is fringed on the west and south by the Galician folded belt that lies at the base of the European Paleozoic and Mesozoic folded stages.

The North-American platform is surrounded on the southeast by the Appalachian folded belt. At its base we also find folded structures of the fifth Precambrian megacycle.

In the southern hemisphere by the end of the fifth Precambrian megacycle, age 550 m.y., the South-American, African, Indian, and Australian platforms had stabilized throughout their territory.

In Africa the folded belts of the Katanga orogenic cycle became stabilized: the Nama-Dodoma-Katanga, the Mozambique, the Pharicides, the Anti-Atlasides, etc.

Within the Indian platform the Satpura, Dehli and Vindhian folded belts of the northern Indian peninsula became stabilized.

In Australia the belt composed of the Precambrian V Bangamalian group dated at 1100–940 m.y. between the Pilbara and Kalgoorlie blocks became stabilized.

In South America the stabilization of the entire South-American platform was culminated by the Carririan orogen with an age of 600–400 m.y.

General consideration of the results of geochronological studies performed on all continents of the globe suggests that the techniques of absolute geochronological determination hold a firm place in the analysis of the formational history of the earth's crust. The age figures of the geological formations, making up structural stages of the crust on different continents, point to a synchronism of the geological processes of formation of the mobile folded zones and of the platform stabilization.

It is established that the North-American and East-European Precambrian platforms of the northern hemisphere became generally stabilized at an age of 1100 to 1200 m.y., and folded belts of the fifth Precambrian megacycle fringe these enormous platforms. The greatest part of the Precambrian V folded belts has been altered by the Paleozoic and Mesocenozoic foldings in the Appalachians, Rocky mountains of North America, in the Alpine-Carpathian-Balkan-Crimean folded belts, in the Scandinavian Lower Paleozoic folded belt and in the Uralian folded belt of the European continent.

There exist in Europe "through geosynclines" dated at 1100 m.y. that went on developing during the fifth Precambrian and sixth Phanerozoic megacycles.

As distinct from the above features, the Precambrian platforms of the southern hemisphere – the south American, African, Indian, and Australian platforms – became stabilized later, only by the end of Precambrian V to Early Paleozoic time, i.e. 550 m.y. ago. There, the folded zones of Precambrian V are preserved unaltered; they lie around smaller platforms composed of Precambrian IV, III, II, and I.

In connection with the consecutive expansion of the Kratogene areas constituted by stabilized folded structural elements of the crust, that had been formed during the five megacycles of the Precambrian, a conclusion might be drawn about the irreversibility of geological processes, i.e. the impossibility of conversion of kratogene areas into mobile folded zones.

However, the following facts are at variance with this conclusion:

In Europe, amongst folded zones of the Phanerozoic megacycle, outcrops of Precambrian formations are found which belong to the second, third and fourth Precambrian megacycles as well as to the fifth megacycle.

In Romania, south of Dobruja, in Palazu Mare, ferruginous-siliceous formations dated at 1850 m.y. have been found, and these are synchronous with the Ukrainian shield Krivoy Rog series.

In Scotland Precambrian formations of early Scourian time, 2600 m.y. old, have been found represented by gneisses of the granulitic facies: the Inverurie, with an age of 2200 m.y., Laxfordian, 1800—1600 m.y., Charian, 1350 m.y., and Torridonian, 1250–1150 m.y.

Amongst the Paleozoic folding in the Urals and within the projecting median massifs, Precambrian formations dated at 2000 m.y. have been found. They were previously represented by the Taratash series.

In the Dehli folded belt, North India, that was formed during Precambrian V, older Precambrian formations also project through the basement.

The present evidence as well as other data are indicative of the conversion, in a number of places, of the kratogenized Precambrian areas into areas of mobile geosynclinal zones.

The above data, showing that the Phanerozoic folded belts are underlain by Precambrian formations, do not agree with the conclusion that the continental crust of the platforms expands at the expense of the oceanic crust by the incorporation of new mineralized structural stages.

ГЕОХРОНОЛОГИЯ СТАБИЛИЗАЦИИ ДОКЕМБРИЙСКИХ ПЛАТФОРМ КОНТИНЕНТОВ

(Р е з ю м е)

В истории развития структуры земной коры в докембрии устанавливается пять мегациклов, с которыми связана перестройка архитектоники континентов, стабилизация платформ и заложении складчатых поясов.

К концу первого докембрийского мегацикла возрастом 2600 (2700) млн. лет стабилизировались протоплатформы, сложенные складчатыми образованиями возрастом 2700-3500 млн. лет и древнее: в Восточно-Европейской платформе - Днепровско-Конкская и Саамская; в Африке - Швазилянд, Нил - С .Конго и Сиерра-Леоне; в Австралии - Пилбара, Калгурли.

К концу второго докембрийского мегацикла возрастом 2000 млн. лет стабилизировались уже крупные платформы, сложенные складчатыми образованиями от 2000 до 3500 млн. лет: в С. Америке - платформы Иеллоунайф и Верхняя; в Ю. Америке - Гвиана; в Африке - Сиерра-Леоне, Биримий, Кассаи, Нил - С. Конго, Танзанийская, Родезия, Свазиленд; в Индии - Дхарвар; в Восточной Европе - Беломорская, Воронежская, Волго-Уральская, Подольская, Днепровско-Конкская; в Восточной Сибири - Алданская (Иенгрская) и Анабарская; в Австралии - Пилбара - Калгурли, Катерин-Дарвин.

К концу третьего докембрийского мегацикла возрастом 1600 (1700) млн. лет стабилизировались крупные щиты, сложенные складчатыми сооружениями возрастом от 1600 до 3500 млн. лет: в С. Америке - Канадский; в Восточной Европе - Балтийский, Украинский, Воронежский, Волжский, Приуральский, в Восточной Сибири - Алданский и Анабарский; в Ю. Америке - Гвианский, Токантинс-Топайос, Сан-Луис, Сан-Франциско, Уругвай - Аргентина; в Африке - Южно-Африканский, Центрально-Африканский, Западно-Африканский и Сахара; в Индии - Дхарвар, Вос. Гхаты; в Австралии - Пилбара, Калгурли, Катерин - Дарвин.

К концу четвертого мегацикла возрастом 1100/1200 млн. лет стабилизировались основные площади докембрийских платформ северного полушария: С. Американская, Восточно-Европейская и Восточно-Сибирская. В южном полушарии образовались крупные платформы, занимающие большую часть континентов: в Африке - Зап.-Африканская, Конго и Калахари; в Австралии - Ю. В. Австралийская и Дарвин; в Индии - Ю. Индийская; в Ю. Америке - Гвиана, Токантинс-Топайос, Рондония, Сан-Франциско и Уругвай.

К концу пятого докембрийского мегацикла возрастом 550 млн. лет только незначительно расширяются С. Американская, В. Европейская и В. Сибирская платформы северного полушария за счет частичной стабилизации складчатых поясов докембрия пять по

краям платформ. В это время к концу докембрия - 550 млн. лет в южном полушарии стабилизируются Южно-Американская, Африканская, Индийская и Австралийская докембрийские платформы.

Таким образом стабилизация докембрийских платформ южного полушария проходит позднее чем докембрийских платформ северного полушария.

В связи с последовательным расширением кратогенных областей, сложенных стабилизировавшимися складчатыми структурными ярусами коры, сформированными на протяжении пяати мегациклов докембрия, можно было бы сделать вывод о необратимости геологических процессов - о невозможности перехода кратогенных областей в подвижные складчатые зоны. Однако, этому выводу противоречат следующие факты:

В Европе среди складчатых зон фанерозойского мегацикла установлены выходы докембрийских образований не только пятого мегацикла, но и второго, третьего и четвертого мегациклов Докембрия.

В Румынии - в южной части Добруджи - в Палазу Маре установлены железисто-кремнистые формации возрастом 1850 млн. лет, синхронные (по времени) Криворожской серии Украинского щита.

В Шотландии установлены докембрийские образования раннего Скурия возрастом 2600 млн. лет, представленные гнейсами гранулитовой фации, Инверия - возрастом 2200 млн. лет, Лаксфордия - возрастом 1800–1600 млн. лет, Чарлия - возрастом 1350 млн. лет иТориодона - возрастом 1250–1150 млн. лет.

На Урале среди палеозойской складчатости в выступающих срединных массивах установлены докембрийские образования возрастом до 2000 млн. лет, представленные ранее Тараташской серией.

В Северной Индии в Делийском складчатом поясе, сформированном в докембрии У, выступают в фундаменте и более древние образования Докембрия.

Эти и другие данные свидетельствуют о переходе в ряде мест кратогенизированных областей докембрия в области подвижных геосинклинальных зон.

Эти данные показывают, что в основании фанерозойских складчатых поясов залегают докембрийские образования. Это не позволяет присоединиться к выводам о том, что континентальная кора платформ разрастается за счет океанической коры путем причленения каждый раз новых минерализованных структурных ярусов.

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