Islamic Azad University
Mashhad Branch

Elkhan A. Mamedov / Iranian Journal of Earth Sciences 3 (2011) / 47-58

Gold Bearing Conglomerates in some Molasse Basins of Iran

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Received 2 July 2010; accepted 20 January 2011

Abstract

This article lists a number of geological data on the conditions of formation of some major gold deposits in the conglomerates of the Earth's crust. We analyze the metallogenic, tectonic, stratigraphic and other factors controlling the formation of gold-bearing conglomerates in certain fields, such as the Witwatersrand (S. Africa) and Darwaz (Tajikistan). The following tectonic factors play the leading role in controlling the formation of deposits of gold-bearing conglomerates in the Earth's crust:

– Epochs of mountain building of different ages in folded belts;
– Epochs of mountain building in activation of consolidated gold ore provinces in the domed uplifts of ancient shields, median areas and in areas with complete folding;
– The role of lithogenesis of the molasse cycle, transgressions and angular unconformity in the formation of gold-bearing conglomerates in a large area;
– Synchroneity with mountain building in gold ore provinces of different, intermountain molasse and marginal basins of various ages; and imposed volcanic and terrigenic conglomeratic molasse basins in activated gold ore provinces
– Volcanic belts and deep faults.

There are three industrial types of gold-bearing conglomerates: ancient Precambrian (indurated) sedimentary-metamorphosed placer, Phanerozoic cemented placer, and younger, weak, friable Pliocene-Pleistocene placers. We give some details about the methods for their exploration and financial costs for the development of selected industrial types of gold-bearing conglomerates.

In this article, it is noted that during the Sassanian and the Mongolian Empire a certain amount of native gold was extracted from the Late Alpine molasse conglomerates which formed during the activation of gold ore area of the major Iranian middle massif.

By analogy with the geological conditions of formation of deposits of gold-bearing conglomerates in the Earth's crust, the geological search criteria for deposits of gold-bearing conglomerates in some orogenic and widespread activated imposed conglomeratic molasse basins of Iran are given. A number of promising molasse conglomeratic basins are indicated: Mashhad intermountain deflection, as well as a number of superimposed molasse basins in the active superimposed volcano- plutonic belt of Iran, in particular Lut Block, middle massif, Tabriz , Ahar , and other superimposed molasse basins in the large Sabalan ring structure.

In conclusion, we propose the development of selected areas and the establishment of new major resources of the gold - placer industry of Iran.

Keywords: *Gold ore province,Gold-bearing conglomerates,Gold placer molasse basin, Mountain building activity,Iran.*

1. Introduction

Gold-bearing conglomerates in the molasse basins of the Earth's crust constitute one of the leading industrial types of gold deposits. In such deposits large resources of gold are concentrated sometimes with uranium, platinum, tin, tungsten and diamonds. Examples of these gold deposits include: the ancient Precambrian conglomerates of the Witwatersrand (Republic of South Africa) as well as younger gold-bearing conglomerates, the Mesozoic-Cenozoic California depression (USA), and late Alpine Darwaz (Tajikistan) among others.

Often these deposits are accompanied by alluvial gold placer deposits. Deposits of gold-bearing conglomerates have played a significant role in the global economy in the past and present.

In Iran, the gold-bearing conglomerates have been little studied, although there are a number of major tectonic structures suitable for the formation of such deposits.

Gold-bearing conglomerates could back up the creation of major mineral resources of the gold placer industry and strengthen the economy of Iran. Analysis of a number of geological criteria for the formation of gold-bearing conglomerates in the Earth's crust, as a basis for forecasting and development of gold-bearing conglomerates in Iran is very timely.

2. Geological conditions of formation of gold-bearing conglomerates in the Earth's crust

In the geological literature, only a few monographs give the geological conditions of formation of deposits

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of gold-bearing conglomerates in the Earth's crust e.g. [1,2]. Gold-bearing conglomerates, in particular from Africa, Americas and Australia are documented in the numerous published works.

One of the main geological criteria for prediction of gold deposits of conglomerates is the tectonic conditions of formation of the Earth's crust as described in a number of fundamental monographs [3]. Some of the classical theories of regional tectonics, in particular concerning the main tectonic structure of the Earth's crust have been presented in a number of fundamental works. They are the key to a correct understanding of the formation conditions of gold-bearing conglomerates in the Earth's crust. According to these works, the Earth's crust consists of three major elements ─ stable platforms, mobile geosynclines and the activated provinces. Gold-bearing conglomerates have formed periodically and repeatedly from the upper Archean to the Quaternary period (inclusive). Analysis of geological history of Earth's crust shows that gold-bearing conglomerates are formed at different times of intense, rapid, revolutionary orogenic activity. Soaring mountain structures with gold deposits are extensively eroded. Gold-bearing rocks and the gold-bearing veins are removed to the molasse basin of accumulation, which are then differentiated i.e., erosion and the formation of gold-bearing conglomeratic molasse basins are synchronous with the formation of the mountains. Several well known tectonic cycles can be distinguished in the history of the Earth's crust: Archean, Proterozoic, Baikalian, Caledonian, Hercynian, Cimmerian and Alpine. Formation of molasse conglomerate basins takes place synchronously at the end of the marked phases of intensive uplift of the mountain. During this period, rapidly rising mountain structures with gold ore deposits are being denuded. This era is widely known as the period which displays phases of folding. For example, the Carboniferous and Permian deposits of gold-bearing conglomerates in the Hercynian fold belt of the Northern Caucasus and the Urals (Russia) or the Jurassic and Upper Cretaceous deposits of gold-bearing conglomerates in the Cimmerian fold belt of California (USA). In these studies the phases of mountain building are considered as part of folding and orogenic phases. In fold belts of gold deposits, conglomerates in the molasse basin occur linearly and are in parallel. In activated provinces of deposits, gold- bearing conglomerates are not linear, but are superimposed. In the fold belts and the activated provinces of the Earth's crust, these processes are often separated in time [4]. Mountain building often begins with belts of small intrusions, subsequent volcanism and the formation of conglomerates of the upper molasse formation.

It should be added, that some researchers consider the molasse formation of orogenic formations [5,6], to be characterized by lower and upper molasse or lower red and upper grey molasse. In the fold belts and the provinces of the Earth's crust, these processes are often separated in time. Mountain building often begins with subsequent volcanism and the formation of the upper molasse in the Earth's crust. We have laid the basis for predicting gold deposits in conglomerates in the Earth's crust (including Iran) based on these new principles. However, the phases of mountain building in the history of the activated provinces of the Earth's crust are poorly developed. Molasse basins which have formed by the process of prolonged revitalization of consolidated tectonic structures are considered in scientific studies [7, 8].

There are two types of superimposed molasse conglomeratic basins: *volcanogenic* and *terrigenous.*

Molasse basins are formed as boundary and intermountain depressions in the fold belt formed during mountain building.

In the period of activation of ancient consolidated tectonic structures a special type of molasse basin is developed ─ imposed conglomerate basins and volcanic conglomerate depression. In general, in widely distributed provinces activated molasse basins, thick strata of conglomerates are present. These powerful, often bouldery conglomerates and transgressive intervals are a reflection of the phases of mountain building. Here are some details about the geological conditions of formation of deposits of gold-bearing conglomerates in the period of mountain building in the molasse basins of activated gold provinces, their stratigraphy and litho-facies formation conditions in the Earth's crust.

Thus, the formation of molasse basins is connected on one hand with orogenic folded belts, and on the other hand with the activation of the consolidated structure of the Earth's crust.

2.1 Deposits of gold-bearing conglomerates in ancient superimposed volcanic molasse basins

Deposits of gold-bearing conglomerates are located in the ancient activated Shield platforms e.g., the deposits of Witwatersrand (South Africa), Blind River (Canada), Jacobina (Brazil) and others.

The gold-bearing conglomerates of Witwatersrand are briefly described below:

● **The Witwatersrand Deposit (S. Africa)** This deposit of gold-bearing conglomerates with uranium, platinum and diamonds in Witwatersrand is located in the Transvaal shield in the southern marginal part of the African platform [9]. The deposit is the largest producer of gold in the world. Ores also contain significant quantities of uranium, as well as platinum and diamond. The area of gold-bearing conglomerates is about 140,000 km^2 with proved reserves of more than 50, 000 tons. Resources are unlimited. Gold-bearing conglomerates are localized around six gold ore volcano-tectonic cupola uplifts: Central Rand, Far East Rand, Far West Rand, Klerksdorp, Odendalsrus and Vredefort. The basement Shield is formed by ancient Early Archean ultrabasic and basic igneous rocks, which were intruded by granites with the age of 3,400-3,000 million years. Ancient granite forms a series of curved structures. The ancient granite is transgressed with an angular unconformity by the volcanic and sedimentary strata of Swaziland System. Then, in the Transvaal era, mountain building produced molasse (the Modis clastic system), the basal conglomerates of which contain fragments of ancient granites.

The Swaziland rock system has numerous gold-quartz veins, which are the source for the formation of gold-bearing conglomerates deposits of the Witwatersrand. After a long break (about 600 million years), in the Eburnian era mountain building activity increased in the Transvaal shield. A shield with circular cupola uplifts entered a new phase of repeated cyclical and rhythmic development, i.e., uplift, mountain building, formation of curved faults, accompanied by andesitic volcanism, the introduction of sub-volcanic intrusions of dikes, and then repeated washing, transgression and molasse lithogenesis. In the lower Proterozoic, simultaneously with the appearance of ancient domed structures, the superimposed Witwatersrand volcanic molasse basin (900x550km) was formed. Synchronized accumulation of powerful volcanic sedimentary molasse strata systems occurred: Dominion, Witwatersrand, Vendesdorp and Transvaal (Fig.1). The edges of superposed Witwatersrand volcanic molasse basin posted a number of ancient cupola ring structures, and with the center-ring ancient cupola Vredefort uplift. This deep trough in the

northeast limited the uplifting of the central Randa cupola, and in the south-west Odenthal Rust. Such ancient ring structures are characteristic of many ancient shield platforms. The total thickness of volcanogenic sedimentary molasse deposits is over 20km.

The long period of development, that is all the lower Proterozoic formation, the volcanic superimposed arc-shaped depression and formation of its gold-bearing conglomerates were controlled by mountain building and several large gold ore ring structures. During this time, the tectonic, structural and mountain building situation in the region changed repeatedly. Naturally, the conditions of the molasse lithogenesis and lithologic environment of sedimentation also changed, with a significant role in lithogenesis being played by volcanism.

Numerous bow-shaped and radial faults, accompanied by minor gold quartz veins are distributed on a deposit site. They played a significant role in the distribution of litho-facies features in the molasse basin.

Deposition of all the four systems begins with interruptions, angular unconformities and often with basal conglomerates. Such basal conglomerates often contain gold, and are developed over a large area. Such regional breaks and transgressions are the criteria for stratigraphic control of gold-bearing conglomerates in the Witwatersrand deposit.

Sites of deposition experienced intensive uplifts and subsidences which weakened and faded by the end of the period, and were replaced by stable conditions. Numerous river placers formed at the end of the early gold-bearing conglomerates.

Lower Dominion suite (0-450m) is mainly composed of acid and medium-sized terrestrial lavas, sometimes with basal assemblage of gold-bearing conglomerates, sandstones and shale.

he overlying Witwatersrand System (6000-8000m) currently is divided into the lower and upper divisions. The lower division is predominantly shale and the upper one includes rich gold-bearing conglomerates and shale. In an average part of system lavas are marked. The deposits of both systems have experienced weak folding and metamorphism.

The Ventersdorp System (1800m): the sequence in the lower part consists of sandstones, conglomerates and shale (250-550m); the upper part is mainly made up of andesitic and more acid lavas and tuffs. The overlying Transvaal System reaches a large thickness (9350m). The Reason suite is composed of basal gold-bearing conglomerates and quartzites with interbedded lavas, and the top sections consists of thick layers of dolomite and limestone. The Transvaal system is much more widespread than the underlying systems and continues outside the basin; it falls squarely on the basement rocks. Details of the structure of deposits of all systems show that the sediments were deposited in a flat shallow foothill depression, on the slopes of the dome uplift, and at the same time, on the coast pulsatory oscillating motion took place against a background of very long dikes and volcanism. The growth of mainly intensive dome-shaped folding gradually faded away. Rhythmic and cyclical vibrations were accompanied by subsequent volcanism. This has led to numerous erosional breaks and erosion.

Most of the prominent conglomerate horizons are transgressive basal strata that were laid after the erosion hiatus. All four systems have industrial gold content in the basal conglomerates and the horizons of conglomerates are confined to the upper section of the Witwatersrand, related to intraformational breaks. The upper division of the system is characterized by sustained Witwatersrand gold-bearing horizons over large areas, which indicates the long-term supply of gold from the source area and intensive mountain-building movement. In the basal conglomerates of Ventersdorp and Transvaal, industrial gold content only occurs where the bed falls within the transgressive conglomerates of the Witwatersrand gold-bearing conglomerates system. Thus gold in the conglomerates is derived directly from the underlying rocks.

About 40 widespread minerals have been reported; gold, uranium, diamonds and sulphides and other minerals which have been used for dating of the cement of conglomerates and formation of minerals during some periods. On these widespread clastic minerals hydrothermal activity was imposed, followed by general metamorphism. The conglomerates are oligomictic with quartz and dispersed gold. The content of gold is 7-20 g/t and uranium 0.11%. The confirmed reserves for gold are 50,000 tons with 300,000 tons of uranium.

In the Witwatersrand deposits 12 gold-bearing conglomerates or ***bankets*** are present. Gold-bearing conglomerates are solid, strong and the mine is operated as a typical primary deposit, and there have been environmental problems.

Analysis of the paleogeographic environment of sedimentation shows that the deposit formed in a shallow marine environment around the cupola ring uplifts in the sediments of the upper molasse formation.

The region has well developed sub- volcanic intrusions i.e., subsequent andesitic and quartz porphyry dikes, which in many gold-bearing volcanic belts of the Earth's crust are closely related in space with gold-silver deposits. They are formed during mountain building.

For a long time the genesis of the deposits of gold-bearing conglomerates of the Witwatersrand has been controversial. There are a number of hypotheses, based on sedimentary-metamorphosed placer and hydrothermal deposition. Analysis of this paper is taken from articles in [10].

It should be noted that since the area is characterized by deposits of gold-bearing conglomerates of many landmark development of tectonism, mountain building, magmatism, metamorphism, faulting, ore formation and molasse lithogenesis, it certainly does not exclude the possibility that the field evidence indicates the imposition of metamorphosed sedimentary gold-bearing conglomerates by local hydrothermal gold mineralization.

In this connection, the imposition of gold-bearing conglomerates by local gold-quartz veins can be seen.

Thus, deposits of gold-bearing conglomerates of the Witwatersrand in the tectonic structures are controlled by the long-developing volcanogenic superimposed depression, molasse litho- genesis and activation of gold provinces in South Africa. Naturally, along other factors, they can be used as geological criteria when searching for deposits of gold-bearing conglomerates in the Earth's crust.

Among the stratigraphic and lithofacies criteria we can note the following:

Gold-bearing conglomerates are confined to the upper part of cycles and rhythms of sedimentation, mainly located in the transgressive series of sedimentation. Such stratigraphic horizons are distributed over a large area. Conglomerates or coarse boulder, which indicates that sedimentation, took place in a shelf or near-shore marine lithologic and shallow environment.

Many controversial issues regarding the Witwatersrand gold-bearing conglomerate deposits disappear, given that the source of gold in the conglomerates was close to the volcano-dome uplifts, rather than tens of kilometers as claimed by advocates of the hydrothermal theory. It is, first and foremost, the question of roundness of gold, that is, the origin of placer gold. Since the source of gold is near, the gold in the conglomerates cannot be rounded in general and gold in the conglomerates retains its primary hydrothermal appearance.

Thus, the geological conditions of formation of the largest deposits of gold-bearing conglomerates of the Witwatersrand are the following:

The tectonically structured deposit is controlled by several ancient dome ring uplifts activated repeatedly. The core of dome uplifts consists of individually folded basement of Late Archean granites, subsequent volcanic rocks and gold ore veins.

Several phases of intense mountain building in the region have played a significant role in the formation of deposits of gold-bearing conglomerates of the Witwatersrand; erosion and volcanic molasse lithogenesis, controlled the formation and deployment of stratigraphically controlled deposits of gold-bearing conglomerates of the Witwatersrand.

At the same time, a role in the spatial distribution of gold-bearing conglomerates was played by the fact that the Ventersdorp volcano-plutonic structural elevation was located inside the island and the gold-bearing conglomerates were formed around the arched island.

These criteria are essential in predicting and exploring for deposits of gold-bearing conglomerates in ancient ledges.

2.2 Deposits of gold-bearing conglomerates in superimposed terrigenic molasse basins

Deposits in gold-bearing conglomerates imposed on terrigenous molasse basins are widespread in the Earth's crust. To this type belong the widely known deposits of gold-bearing conglomerates of the Carboniferous and Permian in Hercynian fold belt of the North Caucasus (Russia), Jurassic and Cretaceous gold-bearing conglomerates of the Mesozoic fold belt California **(**USA), the largest deposits of the Miocene, Pliocene and Pleistocene gold-bearing conglomerates in the Alpine activated province of the Northern Pamir in the Darwaz (Tajikistan). The last is a typical example for deposits of gold-bearing conglomerates.

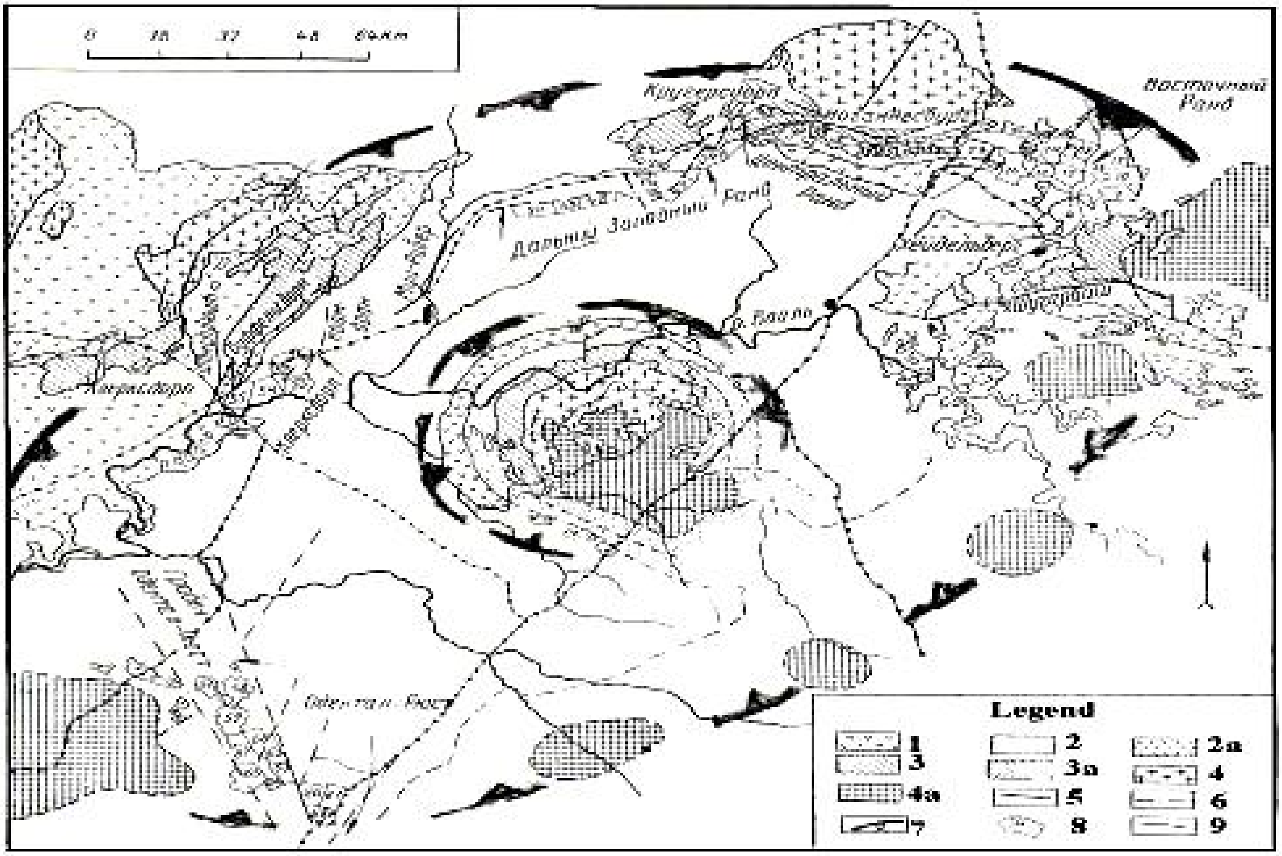

Fig. 1. Schematic geological map of Witwatersrand area (on Du Toit [9], modified by the author).
1-Ventersdorp lavas; 2- upper part of Witwatersrand system; 2a - the upper part of Witwatersrand system under cover of the Karoo System; 3- lower part; 3a -under cover of the Karoo System; 4-ancient granites; 4a - The same under cover of the Karoo System; 5-explosive infringements; 6-assumed explosive infringements; 7 -the areal distribution of bow-shaped faults; 8- dumps; 9-exits of productive gold-bearing conglomerates.

● Darwaz (Tajikistan) Deposits

They are formed in the superimposed terrigenous conglomeratic basins in the activated gold ore provinces of the Northern Pamir. Gold-bearing Neogene conglomerates in Darwaz are located in the North Pamirs in the territories of Tajikistan.The geological succession of the deposit involved the following series: Balujan (Oligocene), Hingou, Tavildara (Miocene), Karanak and Polizak (Pliocene) and Dashtak (Pleistocene). The total thickness is about 5,000 meters. The deposit was studied by numerous geologists. We first discovered and identified 14 rich horizons of gold-bearing conglomerates which are located in the upper molasse formation. In the upper part of Tavildara (upper Miocene) suite-five, in Karanak (lower Pliocene) suite two, in Polizak (upper Pliocene) suite five and Dashtak (Pleistocene) suite two. The total thickness of the auriferous strata is 2500-3000m. These horizons of gold-bearing conglomerates are spread over a vast area. Inferred resources for the four horizons of gold-bearing conglomerates are more than 3000 tons of gold. Unlike other researchers, we first proposed to expose gold-bearing conglomerates by water disintegration in order to know it is a typical placer deposit. Thus, we intend to classify Darwaz deposits into placer class.

The deposit is localized in the south-western part of the Tajikistan in the Tajik-Afghan superimposed basin. It was formed during the Neogene activation of the Paleozoic Maxsu-Souksu Northern Pamir copper-gold belt. Gold from Neogene conglomerates has been mined since ancient times. The mines were particularly intensively worked in the Mongolian Empire, during the rule of Genghiz Khan (Fig.2).

The analysis of the geologic, tectonic, orogenic, metallogenic and sedimentary conditions of formation for the deposits show that gold-bearing Neogene conglomerates of Darwaz were formed in the Tajik-Afghan superimposed molasse basin under shallow continental to coastal-marine conditions in some of the stratigraphic horizons and show four regional transgressions.

Deposits are located in transgressive boulder conglomerates of Tavildara (upper Miocene), Kanaran (lower Pliocene), Polizan (middle Pliocene) and Dashtakin (upper Pliostocene) series which are gold-bearing over a vast area. The total thickness of the auriferous horizons is 2500-3000m.

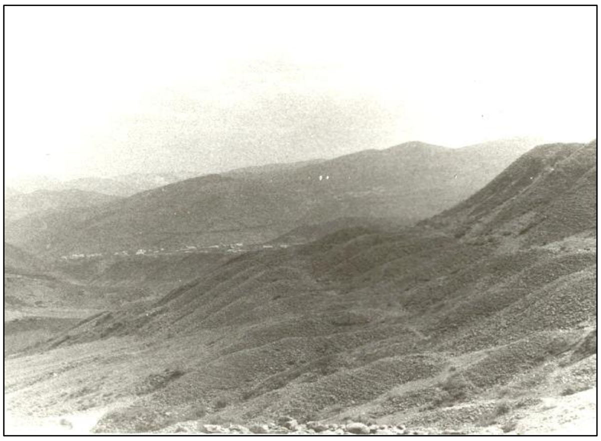

Fig.2. Dumps of mining of native gold from conglomerates in Tajikistan mined during the Mongolian Empire

The gold-bearing conglomeratic sequences show cyclical and rhythmic structure, which is a direct reflection of several phases of mountain building, their weakening and fading over time. The length of the auriferous strata with its breaks is 100 to 150km. Thickness of the gold-bearing conglomerates strata varies from 0.5m to 50m and more. The gold is native and its purity is high, about 23 carat. The size of native gold grains is from 0.3x 0.2 x 0.08mm to 4 x 3 x 0.5 mm (Fig. 3.).

Fig.3. Darwaz (Tajikistan) Deposit: native gold from the cementing material of the conglomerates. Gold grains range from 0.5-3.0 mm, sometimes up to 5.0 mm.

Gold content ranges from 500 mg/m^3 to 10g/m^3. Gold-bearing conglomerates consist of pebbles (50-55 %) and cement (45-50 %). The gold is contained in the cementing material of the conglomerates. Native gold nuggets about 100 gram have been noticed. Gold-bearing beds of the Tavildara and Karanak are weakly cemented; they are easily disintegrated with water while the Polizak and Dashtekin strata are incoherent. Gold-bearing conglomerates are probed by waterjet method with wide, parallel placed channels. Gold-bearing conglomerates belong to the upper molasse formation and they are classified as sedimentary placers (genetic class). In the formation of the gold-bearing conglomeratic strata the latest gigantic mountain building has played the most important role in the Pamirs. The Pamirs is a knot or junction of the highest Alpine mountain structures of the Earth such as Kun-Jun, Hindukush, Himalayas and Tibet. According to the geological-tectonic structure three main zones have been distinguished in the Pamirs: the Northern, Central and Southern Pamirs. All these three zones are auriferous, with numerous copper-gold, gold-quartz-sulphides, gold-sulphide (pyrite) deposits, along with modern alluvial placer deposits of gold. Neogene gold-bearing conglomerates are widespread in the region; they serve as a source for the formation of placers in the rivers. As a whole gold deposits form the regionally extended Pamirs-Hindukush auriferous belt in Central Asia.

High upheaval, crushing and erosion of the gold-ore deposits in the Pamirs-Hindukush auriferous belt during the revolutionary phase of the mountain building (e.g., Tavildara, Safetdara, Sariob and Talbar,) contraction of earth and collision of the separate blocks played a decisive role in the forming of thick beds of gold-bearing basal boulder conglomerates. They are located at the base of Tavildara, Karanak, Polizak, Dashtaka deposits, extending upto hundreds of kilometers. They also have a regional extension and possess huge resources of gold within the Tajik-Afghan superimposed molasse basin. Undoubtedly, they belong to the placer class of sedimentary deposits.

Thus, the gold-bearing Neogene conglomerate of Darvaz in the Tajik-Afghan superimposed basin is the golden crown of Central Asia and promises a new era of gold placer industry of the Alpine-Himalayan activated belt of the Earth's Crust.

Thus, the geological conditions of formation of gold-bearing conglomerates in the Earth's crust are as follows:

- Tectonically, the gold-bearing conglomerates in the molasse basins are most often formed in the era of mountain building in the framework of ancient gold ore shields, median massifs and folded belts of the Earth's crust.
- In fold belts they develop in the marginal and inter-mountain depression, while in activated provinces they are superimposed as volcanic and terrigenous basins.
- In the stratigraphic section of molasse basins, gold-bearing conglomerates form a number of horizons, which are directly connected with the intensive revolutionary phases of mountain building. At the horizons of boulder conglomerates, transgressions and angular unconformities can be correlated with the phases of intensive regional phases of mountain building.

Thus, the higher the mountain building activity, i.e., the larger the number of phases of mountain building, the greater the number of layers of gold-bearing conglomerates which are formed in a large area. Thus, we will establish for the first time a close connection between the formation of gold-bearing conglomerates in molasse basin with epochs and phases of intense revolutionary mountain building in the fold belts and activated gold provinces of the Earth's crust.

Metallogeny of gold in the region is one of the main geological criteria for prediction of deposits of gold-bearing conglomerates.

In all cases, deposits of gold-bearing conglomerates are formed on the slopes of gold ore provinces of the Earth's crust. There are small widespread gold ore-bearing plutonic intrusions, dikes and subvolcanic intrusions, as well as telethermal gold-veins along the deep faults.

Favorable sedimentary conditions for the formation of large deposits of gold-bearing conglomerates are coastal-sea and shelf areas. Gold-bearing conglomerates belong to the upper part of molasse formation.

The genesis of ancient deposits of gold-bearing conglomerates is complex, i.e., mainly metamorphosed sedimentary placers, and the younger sedimentary placers. In younger deposits, the genesis of gold-bearing conglomerates does not raise any doubts. Many gold-bearing conglomerates are accompanied by younger river accumulations of gold, i.e. in the form of combined gold-bearing conglomerates and gold-bearing river placers.

Imposed terrigenous molasse basins located on the slope of the copper-gold belt, is one of the geological criteria for predicting gold-bearing conglomerates. Here, as in volcanic molasse basins, regional stratigraphic breaks play a significant role in the formation of gold-bearing conglomerates.

Along with geological criteria for prediction of gold deposits of conglomerates, there are several prerequisites that must be considered when looking for deposits of gold-bearing conglomerates. This is the role of financial issues and economic problems.

The exploration and development of ancient gold-bearing conglomerates requires enormous financial costs. The cost of search and development of younger Phanerozoic gold-bearing conglomerates are not large, but involve the integrated development of mineral resources; i.e., the use of industrial wastes in construction industry which does not have significant costs.

After gold mining from Phanerozoic conglomerates, boulders and gravel production wastes can be utilized on sites where extraction has been made. Frequently production wastes are used in the building industry: in the construction of roads and in iron-concrete designs. Deep horizons of Phanerozoic deposits of gold-bearing conglomerates can be mined by hydro- extraction methods.

Thus, the analysis of the geological conditions of formation of some gold-bearing conglomerates in the Earth's crust shows that the molasse basins in the gold ore provinces of fold belts and activated provinces of the Earth's crust have large resources of gold. The formation of such deposits is controlled by tectonism, magmatism, metallogeny and other criteria that were cited above. Deposits of gold-bearing conglomerates in the activated gold ore province are formed in superimposed volcanic and superimposed terrigenous depressions.

Deposits of gold-bearing conglomerates in the folded belts are located at the boundary and intermountain molasse basins.

An essential element of prediction is the presence of metallic gold ore belt at the contact with the molasse conglomeratic basin. For the prediction and search for deposits of gold-bearing conglomerates in the molasse basins it is necessary to consider the role of intense revolutionary mountain building and erosion, which is recorded as transgressive angular unconformities, cyclical and rhythmic molasse lithogenesis, accumulation of gold-bearing veins and rocks and their differentiation in the molasse basin

3. Prediction of gold-bearing conglomerates in the molasse basins of Iran

The history of geological development, of Iran includes tectonism, magmatism, metallogeny, the extraction of gold from conglomerates in molasse basins, as well as the presence of molasse basins with alluvial river deposits of gold. All of this is very promising for the detection of deposits of gold-bearing conglomerates in the molasse basin. Thus, all of the geological conditions are basic, which must be taken into account when predicting gold-bearing conglomerates in Iran. These factors complement each other when looking for deposits of gold-bearing conglomerates in Iran.

For an analysis of geological criteria of gold-bearing conglomerates in Iran, we begin with the history of gold mining conglomerates, as these facts directly indicate the presence of gold-bearing conglomerates in Iran.

3.1 Mining of Gold-Bearing Conglomerates in Iran

The history of mining gold-bearing conglomerates in Iran can be divided into four periods: the ancient, the Sassanian Empire, the Mongolian Empire and the Modern period.

• ***Ancient period***: Gold placer deposits have been developed since ancient times in the Middle East, including Iran. During ancient times placer deposits of native gold were developed in the southern part of Iranian Azerbaijan in Yengeh Kand, Zarrehshuran. In the same locality, in Gareh Bagh village, for the first time mercury has been employed for concentration of small amounts of native gold by working out of river placers in ancient times. These gold-bearing areas show a widespread development of young Pliocene-Pleistocene conglomerates.

During the reign of Persian emperor Darius I (550-486 B.C.) gold monetary coins were made for the first time in the country from native placer gold.

• ***Sassanian Empire period (224-651A.D.):*** Gold was mined in several regions on the territory of Iran e.g., in the vicinity of Kerman, at Kuh-e-Zar in the southern regions of Damgan, at Takht-e-Solyman in Takab, Mazandaran, Jiroft and in other places.

It should be noted that widespread young conglomerates occur in areas of Kuh-e-Zar, Takht-e-Solyman and Jiroft. There is historical evidence for presence of large native gold grains at Takht-e-Solyman.

• ***Mongolian Empire period (1206-1368A.D.):*** Numerous placer deposits of native gold, basically gold-bearing conglomerates were developed for centuries in Iran during the Mongolian Empire (1206-1368A.D.). During this period, Pliocene-Pleistocene gold-bearing conglomerates were exploited in northern Iran (Kuh-e- Zar) and in the southern part of the Great Dasht-e- Kavir depression.

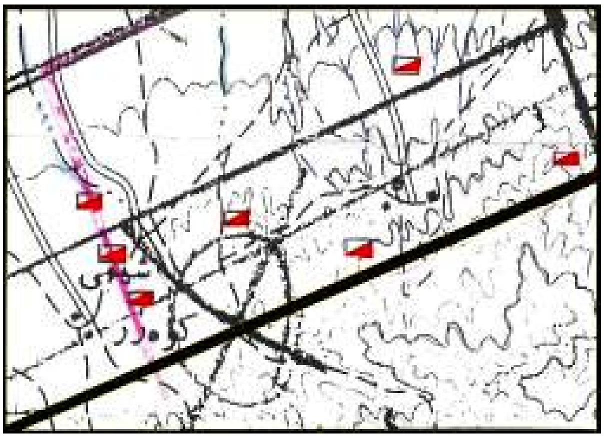

Fig. 4. Ancient gold mining in conglomerates at Kuh-e-Zar, in Iran, during the Sassanian and Mongolian Empires

The region has preserved many old mine workings, which according to the local residents, were associated with tunneling during the Mongolian Empire (Fig.4). This region does not have surface water. For water, they dug Kariz. Weakly cemented conglomerates containing native gold were disintegrated with water (Asian method). Native gold mining was carried out from unconsolidated placer deposits of gold.

This period was the heyday of extraction of native gold from the molasse conglomerates. In Iran, some of these areas have been known since the period of the Sassanian Empire. Having discovered a method for disintegration of dense conglomerates with water, native gold was mined from the vast territory of the Mongolian Empire, including in Iran.

• ***Modern Period:*** At present, in connection with the industrialization of the country, Iran has conducted search for mineral deposits, including deposits of gold. A number of gold-bearing areas were identified including large deposits of gold like Muteh. Gold content of some copper and polymetallic deposits has been documented in a number of fundamental monographs. The Geological Survey has created a number of laboratories for the ore beneficiation.

Iran has conducted systematic geological research in prospecting, exploration and exploitation work in copper, iron, lead, zinc, gold and other minerals. A new mineral resources map, including gold deposits has been prepared. Large foreign geological companies are involved in the study of mineral deposits in Iran. Significant foreign specialists and companies have been attracted for the study of mineral deposits, and a large number of internet web pages have been created − Minerals Information of Iran (www.gis.ir), National Geosciences Database of Iran (www.ngdir.ir) among others.

During this period, gold- bearing Pliocene conglomerates were discovered in the Anarak area. Dr. Elkhan. A. Mamedov held regional studies of gold-bearing conglomerates of Iran for about one year in 1993-1994.

Thus, the analysis of a brief history of gold mining and research on gold-bearing conglomerates in Iran shows that these conglomerates in Iran have been known since ancient times: in particular, the Pliocene-Pleistocene gold-bearing conglomerates in the Kuh-e-Zar in the southern part of the clastic molasse depression (Dasht-e-Kavir in Takht-e-Solyman in Takab molasse depression) as well as the presence of Pliocene gold-bearing conglomerates in the south-western part of the Dasht-e-Kavir depression over Anarak area.

3.2 Short history of geological development and the formation of gold-bearing conglomerates in the molasse basins of Iran

The territory of Iran has a long, varied and complex geologic history, including tectonism, magmatism, metallogenic development and sedimentation. From the position of the geological conditions of formation of gold-bearing conglomerates the following stages of development can be considered: Baikalian, Mesozoic and Alpine.

Baikalian stage: The formation of gold-bearing granites of Doran is linked with the history of geological development of the Precambrian basement complex platform. In the Lake Baikal metallogenic epoch, these granites were closely linked to the formation of large gold-pyrite- chalcopyrite deposits of Muteh, as well as several non-similar large gold deposits in Iran.

In the Eocene and the Pliocene due to intense activation of mountain formation and erosion of ancient Precambrian domes, (which is obviously a fragment of the Iranian middle massif) boulder conglomerates were formed on the slopes of the Muteh deposit. Naturally, these areas are promising for the search of auriferous conglomerates (Fig.5.).

Fig. 5. Boulder conglomerates in the north-western part of Muteh gold deposit

It is necessary to take into account the following fact: Muteh gold deposit contains very small, finely dispersed gold in conglomerates and chemical methods are necessary to determine the concentration of gold.

In Iran, the dome-shaped protrusions of the Baikal folded platform basement with the development of Doran granites are typical for such areas as Bafq, Alborz (Lahijan), Zanjan, Takab and others. These protrusions are surrounded by boulder conglomerates and these areas also deserve evaluation for gold in the conglomerates.

Mesozoic stage: In the early Mesozoic phase of development, during the Triassic-Jurassic, the Iranian Binaloud strata were deposited. At the end of the Lower Jurassic, during the early phase of Caledonian orogenesis, terrigenous sediments were involved in folding and metamorphism with the simultaneous intrusion of granites and the formation of gold-quartz veins sometimes along with tungsten.

Two points of view exist about the age of Binaloud metamorphosed strata. Some consider them Precambrian and others Triassic-Jurassic [11]. We have adopted the latter interpretation.

Later, conglomerates with fragments of gold-bearing quartz veins were formed in the Mashhad molasse basin during the Jurassic in connection with the geological development of the region in the late Nevadan phase of intense mountain building and erosion. It should be added that there are many rivers flowing through the Jurassic auriferous quartz conglomerates. This fact gives us reason to predict and search for the detection of deposits in the Jurassic gold quartz conglomerates of the Mashhad terrigenous molasse basin.

It should be noted that widespread quartz-gold veins cover lower Cretaceous quartz conglomerates in part of Jurassic Davlatiyar (north Toruda), uplift. These quartz conglomerates also deserve evaluation for gold content.

Alpine stage: A considerable part of Iranian territory in the period of alpine development was present as a major Iranian median mass located in the northern part of Arabian platform.

In the early stage of development of the Alpine region, the northern part of the Arabian platform has been regenerated, activated and broken by numerous deep faults trending north-west, north-south, east-west. Thus, a ring and activated areas in the median individual arrays, and numerous small blocks were formed such as the large Lut Block median array and a number of small blocks.

In connection with the activation of Iranian median mass and its fragments along the deep faults in the Cretaceous, several differently oriented extended hyperbasite and ophiolitic belts were formed in Iran. It should be noted that this geological situation was linked with the formation of several low-temperature gold deposits in the Lesser Caucasus and Iran. In the Paleocene and especially in the Eocene the prominent volcanic belt of Iran was imposed along the deep activated fault: Urumieh-Dokhtar around Lut median massif in southern Alborz. The volcanic belt mainly consists of volcanic-plutonic complex of andesite, rhyolite, trachyandesite lavas and tuffs, subvolcanic intrusions, granites and so on. Lower Alpine epoch is one of the main metallogenic epochs of formation of gold ore deposits and furthermore several mines of copper, lead, zinc and rare metals, are known around the Iranian median mass and its fragments [12, 13].

A new stage in the geological history of Iran begins in the Oligocene-Anthropogene (Holocene). This epoch of Alpine orogenesis involved intense mountain building in the activated provinces. This was the period of formation of many large batholiths such as Ordubad (Oligocene-Miocene), on the Nakhichevan-Armenia border. This epoch of formation along the deep fault zones separates the complex of small intrusions

(Pliocene) and numerous polymetallic deposits i.e., molybdenum-copper-gold, as well as complex ore formations e.g., gold-lead-zinc-antimony-mercury [14].

This period was a period of active violent tectonic, magmatic, metallogenic, metasomatic processes and formation of extended superimposed terrigenous and volcanogenic molasse conglomeratic depressions, such as Great Dasht-e-Kavir, Gavkhuni, Jaz Murian, Qizil Uzan, Qom, Ardekan, Lut and Ahar. Some superimposed volcanic conglomerate depressions are located in and around the large circular structure of Sabalan: Tabriz, Ahar, Sangavar Chay, Talish Mountains and others. In Iran, a vast area ranging from East Azerbaijan to the south-east Iranian volcanic belt is located within the young molasse depressions in the form of "islands". The geological situation reminds us of Vredefort deposits of gold-bearing conglomerates of the Witwatersrand. That is, here too the volcanic "islands" may be surrounded by gold-bearing conglomerates.

In molasse basins with gold-bearing conglomerates, the river current flowing over the conglomerates located within the young molasse depressions gets enriched in gold. In the superimposed volcanic molasse basins, numerous horizons of conglomerates belonging to Lower Red (Oligocene), Qum (Oligocene-Miocene), Upper Red (Miocene), Bakhtiari (Pliocene) and the Pliocene-Pleistocene formations are present. Often, these conglomerates contain fragments of gold veins, magmatic rocks and hydrothermally altered rocks of Eocene age. In some molasse basins rivers flowing over the conglomerates have placer gold. In this case, alluvial deposits of native gold are one of the main criteria of forecasting gold-bearing conglomerates in the molasse basins of Iran.

Thus, in the Alpine stage of development in Iran, there were a number of very favorable geologic, tectonic, metallogenic and other factors controlling the formation of deposits of gold-bearing conglomerates in the molasse basins, the most important of which are the following:

– Availability of a large Iranian middle massif and its fragments formed as a result of activation in the Alpine stage of development of the region;
– The formation of several large gold volcanic belts along and around the median massifs and the débris associated with their extended volcanic and terrigenous molasse conglomeratic basin;
– Availability of ultrabasics and ophiolitic belts with gold mineralization and associated with the conglomeratic molasse basins;
– Presence of modern river placer gold deposits in the conglomeratic molasse basins;
– Extraction of gold from the conglomerates.

Some examples of molasse conglomeratic basins, very promising for the formation of gold-bearing conglomerates in Iran are given below:

• Mashhad Intermountain molasse conglomerate depression :

The northern part of the Binaloud gold area sometimes associated with copper and tungsten. A number of modern river placers contain gold, sometimes with tungsten (Fig.6)

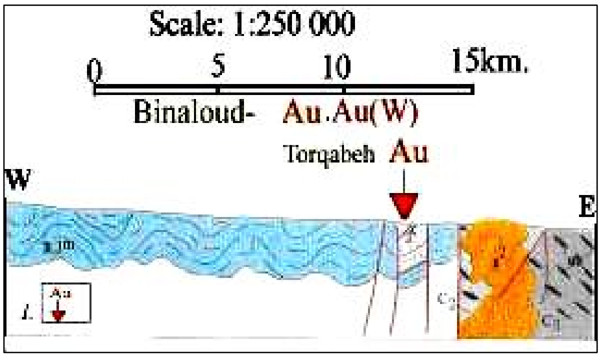

Fig.6. Mashhad terrigenous molasse basin; prediction area with gold-bearing conglomerates. 1. Promising area is the proliferation of Jurassic quartz conglomerates.

• The Great Dashte Kavir Superimposed molasse Depression

South part of the depression: Kuh-e Zar gold ore area. Prospective area of the spread of the Pliocene-Pleistocene gold-bearing conglomerates (Fig.7).

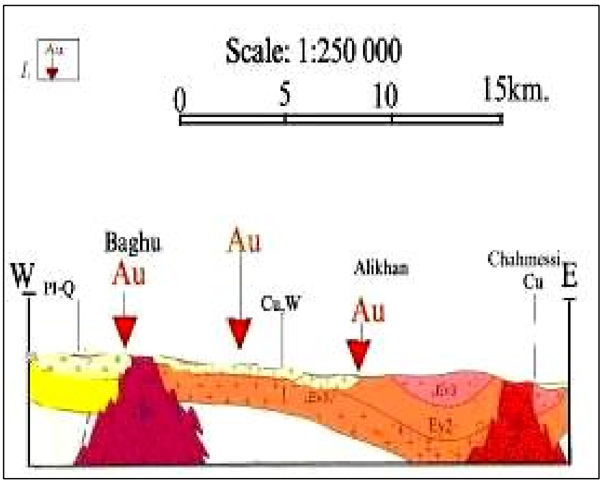

Fig.7. Southern part of the Great Dashte Kavir depression. 1. Prospective area of distribution of the Pliocene-Pleistocene gold-bearing conglomerates.

Alpine superimposed volcanic gold-copper belt with a number of placer alluvial gold occurrences.

• The Takab Molasse conglomerate depression

The central part of the gold-polymetallic volcanic ore field at Baycheh Bagh. A number of gold river placers (Fig.8) are known.

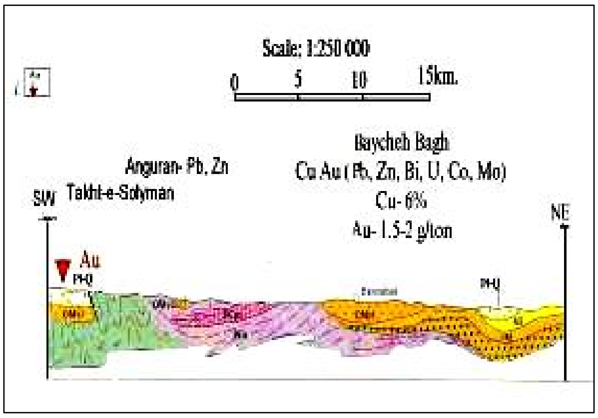

Fig.8.Takab Molasse conglomerate depression. 1. Section of the area of distribution of the Pliocene-Pleistocene gold-bearing conglomerates

• The Ahar superimposed molasse depression

Southern gold-copper volcanic ore field at Ahar. A number of river placer gold occurrences are present. Prospective area comprises the Neogene gold-bearing conglomerates of Ahar imposed molasse basin (Fig.9).

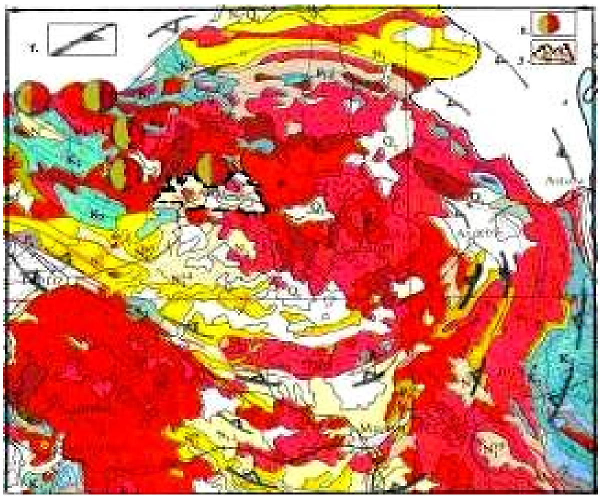

Fig. 9. Location of Ahar molasse basin in the Sabalan ring structure. 1. The Sabalan ring structure 2- Gold-copper ore 3- Ahar molasse basin.

• **Other later alpine imposed molasse basins**

A number of river placer deposits of native gold have been formed in the zones weakened by tectonic activity.

4. Conclusions and suggestions: creating major new mineral resources for the placer gold industry in Iran

In Infra-Cambrian, Jurassic, Cretaceous, Eocene, Oligocene, Miocene, the Pliocene and the Pliocene - Pleistocene, in connection with the era of Lake Baikal, the Mesozoic and Alpine orogeny (i.e., intense revolutionary uplift) erosion and destruction of gold-bearing areas of different ages have produced some pretty prospective gold-bearing conglomerates in the molasse basin in Iran. (Fig.10.).

Fig.10. Predicted molasse conglomerate basins in Iran

Phanerozoic gold-bearing conglomerates are characterized by large resources of gold, and simple technology development. Some of them are exposed on the surface of the earth. Here they are convenient for long-term prospecting, exploration and mining of gold, thus creating a large mineral resource base of placer gold industry in Iran.

So, the territory of Iran is a large placer province with gold-bearing conglomerates in molasse basins.

Acknowledgment

I am sincerely thankful to Prof. Ali Darvishzadehh and Prof. Habib Mollai for support of research on gold-bearing conglomerates in Iran, as well as Rahim Dabiri for assistance in adjusting the English language.

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