Influence of paleostresses in controlling the gold mineralization in Lubok Mandi area, Peninsular Malaysia

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Abstract: The geology of Lubok Mandi area, Terengganu is very interesting especially its geological structures which control the overall geology of the area. A detailed geological study was conducted at part of the PCCL Sdn Bhd Gold Mine that show very good rock exposures. The underlying bedrock is dominated by metasedimentary (slate and phyllite) and volcanic rocks (tuff, tuff lapilli and litihc tuff), calcareous sandstone which in some places are carbonaceous. This rock formation of Middle Carboniferous to Permian in age, is cut by dacite intrusion and quartz veins. The major geological structural trends in the Lubok Mandi area are aligned in WNW-ESE and NNW-SSE directions These structural trends were intercepted by several fault zones which could be classified as either thrust right lateral slip fault and sheared or right lateral slip fault zones. The directions of N(300°-320°)E or WNW-ESE show thrust right lateral slip faults and most of the high angle faults in the directions N(345°-355°)E or NNW-SSE show right lateral slip, while those in N(045°-060°)E or NE-SW directions indicate right lateral slip faults. The mineralization in the quartz veins and wall rocks was also related to the intensive alteration by silicification, argillization and propilitization (chloritization) dominantly around the right lateral fault zones (NNW-SSE). The stress history or paleostresses in the area, which were operating at the time or after the formation of the fault planes, determined the movement or slip that took place on the fault planes. At the same time the paleostresses also governed the orientation of the gold-quartz veins which are related to the gold mineralizations of the area. Paleostresses determination or reconstructionis was done by using all the available slip data of the meso structures observed on the fault planes. The paleostress history is constructed based on the cross-cutting relationship and the displacement of the fault zones. Generally, the gold mineralization in the quartz veins is related to and follow the NNW-SSE fault and shear zones. Among the common minerals observed are chalcopyrite, arsenopyrite, sphalerite, goethite and pyrite. Based on the fault slip data of the meso-structures (fault planes, pitch and pitch directions), the direction of paleostress was obtained. The first paleostress that was acting from NNE-SSW (σ_1=10°-11°, N183°-198°E) controlled the formation of WNW-ESE thrust fault zones and quartz veins, while the second was NE-SW (σ_1=04°-16°, N194°-203°E) controlled the NNW-SSE right lateral fault zones and quartz veins. The third paleostress was acting from ENE-WSW (σ_1=18°-21°, N 232°-236°E) and is related to the NE-SW right lateral fault zones. The WNW-ESE and NNW-SSE quartz veins are related to the compressional paleostresses. The NNW-SSE quartz veins related to the right lateral slip fault zones are high-grade gold mineralization, especially those in the form of quartz breccia.

Abstrak: Geologi kawasan Lubok Mandi menarik untuk dipelajari, terutama struktur geologi yang dominan mengawal permineralan dan geologi secara am pada kawasan ini. PCCL Sdn Bhd adalah syarikat perlombongan emas yang menjalankan aktivinya di kawasan ini. Pengambilan data geologi di kawasan perlombongan sangat baik untuk analisis struktur dalam hubungannya dengan kawalan permineralan. Batuan metasedimen (batu sabak, filit), batuan volkanik (tuf, tuf berbatu, tuf lapilli) dan batupasir berkapur dengan di beberapa tempat terdapat batuan yang mengandungi karbon. Formasi batuan ini berumur Karbon Tengah - Permian, batuan dasit dan telerang kuarza memotong hampir semua satah daripada formasi ini. Struktur geologi secra am mempunyai arah kelurusan WNW-ESE (N300°-320°E) merupakan jalur sesar naik geser kanan dan arah kelurusan NNW-SSE (N345°-355°E) yang merupakan sesar mendatar geser kanan serta beberapa arah NE-SW (N045°-060°E) merupakan sesar mendatar geser kanan.
Permineralan pada batuan dinding dan telerang kuarza berhubungan dengan perubahan batuan pensilikaan, penargilikan, penpropilitan dan penkloritan yang sangat dominan disekitar jalur sesar mendatar (NNW-SSE). Sejarah tegasan kuno (paleostresses) ditentukan berasaskan pengukuran semua unsur struktur, terutama arah pergerakkannya pada satah sesar samada yang major mahupun meso struktur. Selanjutnya hasil pengukuran dan analisis struktur tersebut ditafsirkan berhubungan dengan proses terbentuknya telerang kuarza yang banyak mengandungi permineralan emas di kawasan ini. Permineralan emas di kawasan ini yang sangat baik adalah pada jalur telerang kuarza yang mengikuti rekahan rincih dan jalur sesar mendatar NNW-SSE, dengan mineral yang hadir diantaranya pirit, kalkopirit, arsenopirit, sfalerit, goetit dan manganese. Berasaskan analisis struktur tersebut di atas dapat ditentukan bahawa tegasan kuno pertama terjadi pada arah σ_1=10°-11°, N183°-198°E yang ditafsirkan mengawal pola sesar naik dan beberapa telerang kuarza. Tegasan kuno kedua terjadi pada arah σ_1=04°-16°, N194°-203°E, ditafsirkan mengawal pola sesar mendatar geser kanan (NNW-SSE) dan telerang kuarza yang berhubungan dengan arah ini. Tegasan kona ketiga dengan arah σ_1=18°-21°, N232°-236°E yang ditafsirkan berhubungan dengan kawalan pola sesar mendatar geser kanan (NE-SW). Telerang kuarza dengan arah am WNW-ESE dan NNW-SSE adalah berhubungan dengan pola tegasan mampatan. Berasaskan analisis geokimia didapati telerang kuarza dengan arah dominan NNW-SSE mengandungi anomali emas yang tinggi, terutama pada breksi kuarza di jalur sesar.

INTRODUCTION

The Lubok Mandi area is about 10 km southeast of Kuala Terengganu and is part of the Eastern Belt of Peninsular Malaysia. At present, the PCCL Sdn Bhd Gold Mine Company is exploiting for gold in the area. The gold mineralization is associated with quartz veins and fault systems. The fault systems and the nature of the quartz veins are very much related to the paleostresses history in the area. In order to understand the mineralization pattern, a study was conducted to determine the paleostress by using the slip direction observed on the fault planes. This paper will discuss the method used in this study, paleostresses direction, the timing of deformation related to each paleostress, the nature of deformation either compressional or tensional and relationships between the paleostress history and gold mineralization in this area. Further more, the result of this study would contribute to the understanding of the regional tectonic history of Peninsular Malaysia.

GEOLOGY OF THE LUBOK MANDI AREA

The Lubok Mandi area is covered by tuff, tuff lapilli, calcareous sandstone and metasedimentary rocks (slate, phyllite) which in some places are carbonaceous. This rocks formation is Middle Carboniferous to Permian in age (MacDonald,1968 in Gobbett,1973). Detailed field investigation found that this area dominantly consists of calcareous sandstone with volcanic rocks (tuff, tuff lapilli, breccia) and metasedimentary rocks (slate and phyllite), trending about NNW-SSE and dip towards NE and SW with strike and dip (330°-350°)/(50°-80°)E. The thickness of the volcanic rocks unit is more than 100 m and the metasedimentary rocks unit are between 200-400 m. The general structural trends in the area are aligned in NNW-SSE and WNW-ESE directions. There are three fault systems striking NNW-ESE, WNW-ESE and a few in NE-SW. The NNW-SSE striking faults are known as Lubok Mandi shear. It is believed that the fault system controls the gold mineralization in the area. Field investigations found thrust right lateral slip fault zones trending N(300°-330°)E, right lateral slip fault zones N(345O-350°) E and minor right lateral slip fault zones N(030°-050°) E.

The Lubok Mandi Gold Mines is divided into two main areas, namely North Lubok Mandi and South Lubok Mandi areas. Generally, the orientation of the quartz veins follows the shear and fault zones. Most of the drag folds within the shear zones and thrust faults were filled by quartz. The quartz veins that cut the rock strata in the area followed lateral fault zones and in same places they either follow the strata or moved upwards to form stockwork. Apart from quartz veins, mineralization is also present as disseminations in the wall rock.

Dacite intrusion in the form of dykes or sills cut the volcanic and metasediment rocks. The width of the dacite sills and dykes is between 2 to 40 cm.

METHODOLOGY

Fault and fracture data (mesoscopic structural data) such as the fault or fracture plane, pitch and slip direction were measured and classified according to their general orientation. From their relationship, as they were observed in the field, the relative age of each fault or fracture group could be determined (Angelier, 1979, 1989).

The orientation and mesoscopic structural data of shear fractures, fault striations and some major fault planes were measured from outcrops in the Lubok Mandi area. All the measured data were grouped according to their location, namely North Lubok Mandi domain and South Lubok Mandi domain.

All the data of the mesoscopic structures were plotted using a computer program STRESS 2.2 (Angelier, 1979, 1989) together with stereographic analysis.

NORTH LUBOK MANDI DOMAIN

North Lubok Mandi domain was divided into three sub- areas numbered 17, 29 and 16. The fault structural elements in this domain were measured from volcanic rocks, tuff, lapilli tuff and calcareous sandstone. At location 17, six measurement were collected from a right lateral slip fault zone with strike and dip, 355°/70°E. The analyses gave the compression with σ_1=16°, N203°E. At location 29, five fault structural elements were measured from a right lateral fault zone with strike and dip, 350°/75°E, and the result indicate that the slip were related to a compression with σ_1=04°, N194°E. At location 16, six measurements were conducted from two right lateral slip fault zones, 345°/70°NE and 350°/75°NE and compressions with σ_1=18°, N203°E (Figure 1).

The results of the analyses in North Lubok Mandi domain indicate three directions of paleostresses. They are compression with σ_1= 16°, N203°E, σ_1= 04°, N194°E and σ_1= 18°, N203°E all of which was responsible for the formation of the right lateral slip fault (345°-355°/ 75°NE).

SOUTH LUBOK MANDI DOMAIN

Fault structural elements in this domain were measured from phyllite, slate ,tuff, tuff lapilli and calcareous sandstone. South Lubok Mandi domain was divided into nine sub-areas known as location 08, 18, 32, 14, 12, 30, 03, 10 and 26. From the analysis of fault structural elements at location 08,18,32 three compressional directions were obtained, namely the compression with σ_1=11°, N198°E, σ_1=10°, N183°E and σ_1=07°, N185°E all which were responsible for the formation of the thrust right lateral slip fault zones. At locations 14, 12 and 30 analysis of fault structural elements from NNW-SSE right lateral fault zones indicated compression with σ_1= 23°, N214°E, σ_1=07°, N200°E andσ_1=09°,N 196°E. Finally, at locations 03, 10 and 26 analysis of fault structural elements indicated compressions with σ_1= 18°, N232°E, σ_1=19°, N052°E and

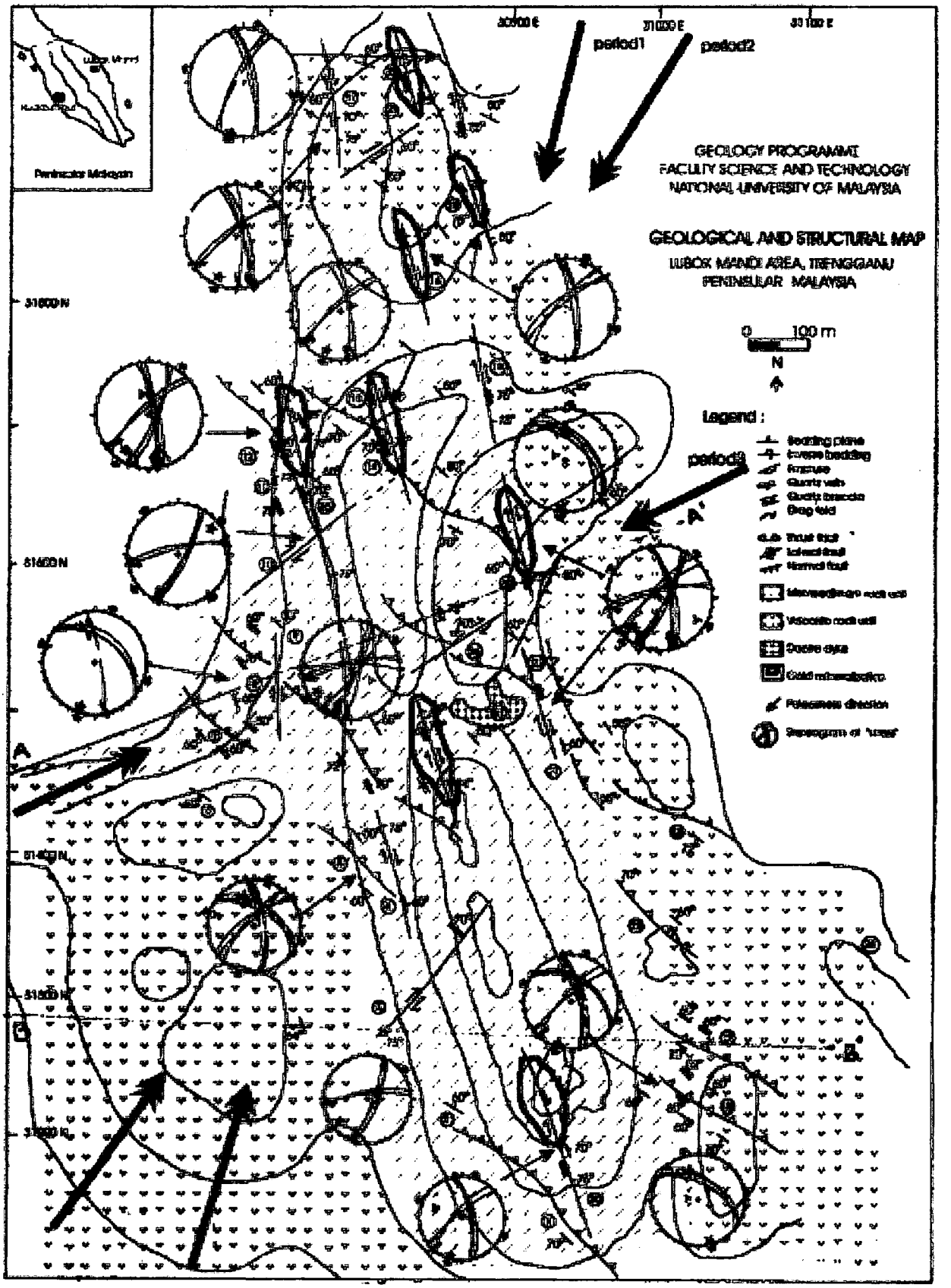

Figure 1. Geological and structural map of the Lubok Mandi area.

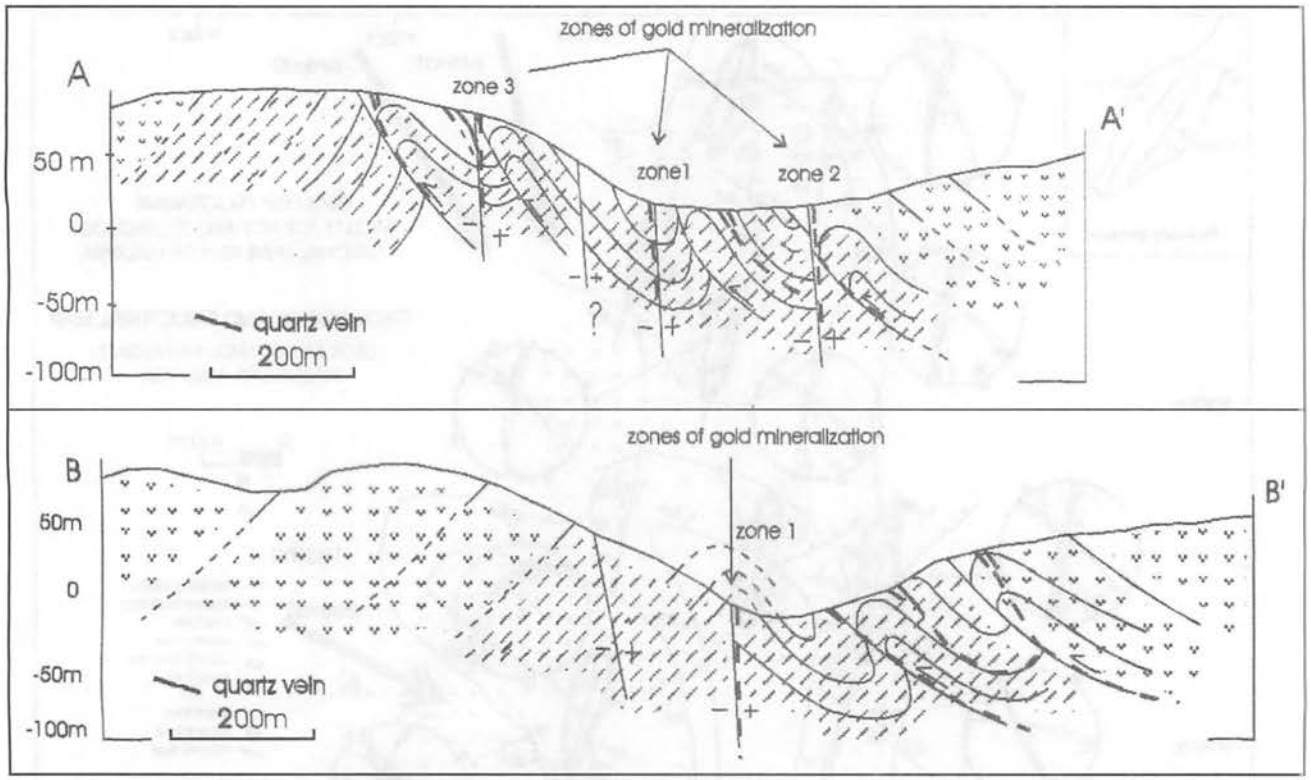

Figure 2. Geological sections of Lubok Mandi. Geological sections along A-A' (top) and B-B' (bottom)showing gold mineralization (top).

σ_1=21°, N236°E were responsible in the right lateral slip fault zones with NE-SW direction (Figure 1).

ALTERATION AND MINERALIZATION

In the Lubok Mandi area wall rock alteration was intensive. The evidence of alteration can be observed in the vicinity of fault zones and quartz veins. In the field alteration in form of silicification, chloritization, seritization and argillization were recognised. Mineralization occurred in several occasions, namely within sheared zones, fault zones, quartz veins, and quartz veinlets in wallrocks.

Based on field observations and analysis of polished sections some sulphide minerals have been identified. Among them are pyrite, chalcopyrite, arsenopyrite, sphalerite and native gold. Sphalerite, arsenopyrite, and pyrite were formed earlier, most probably before brittle deformation took place. Gold, chalcopyrite, pyrhotite and some pyrites were formed at a later stage, during brittle deformation (Figure 2). Late magmatic fluids came out later following the sheared zones, fault zones and several compression and extension fractures (Figure 3).

Gold and associated minerals are present in the quartz veins, which follow the sheared and fault zones. AAS analysis identified high-grade gold mineralization in quartz veins with direction NNW-SSE, filling up some parts of NNW-SSE shear and fault zones. Fluid inclusion analysis from a quartz vein gave a temperature of approximately 196°C. From the information above, it is clearly shown that the gold mineralization in the Lubok Mandi area is of quartz-sulphide type.

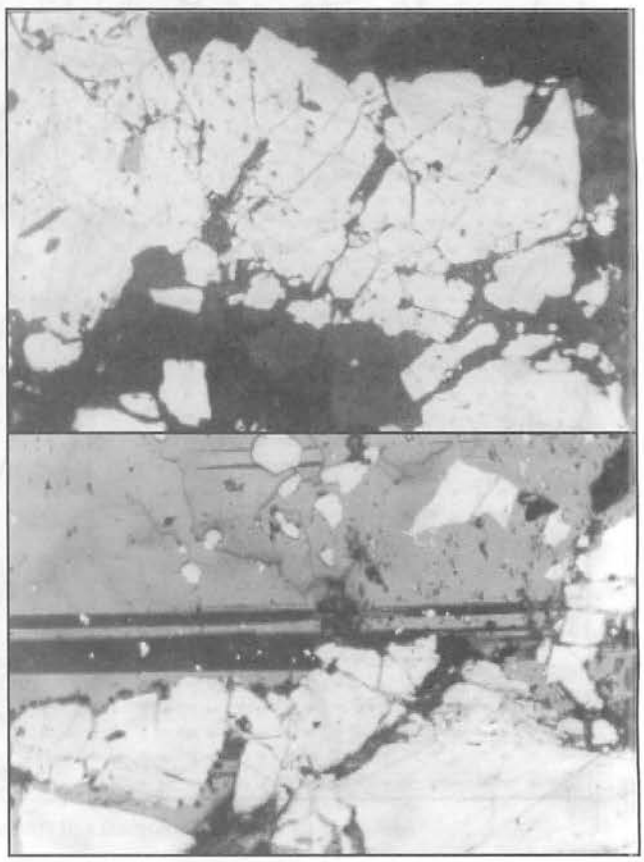

Figure 3. Photomicrographs showing cataclastic texture in pyrite and chalcopyrite filling the fractures in pyrite (top) and gold and chalcopyrite filling in pyrite fractures (bottom).

CONCLUSIONS

Based on the analysis of the structural element data measured in the area, the geology, field evidences on the cross-cutting relationships and sense of displacement along the faults, it is concluded that a sequence of paleostresses operating in the area is as follows:

1. The first paleostress was compression with σ_1=10°-11°, N183°-198°E, which were related to the formation of the WNW-ESE thrust right lateral slip fault zones. There are quartz veins associated with these fault zones.
2. The second paleostress was compression with σ_1= 04°-16°, N194°-203°E, forming right lateral slip fault zones in NNW-SSE direction, also associated with quartz veins. The quartz vein zones are of high grade gold mineralization, especially those in the quartz breccia.
3. The third paleostress was compression with σ_1=18°-21°, N232°-236°E that formed right lateral slip fault zones with direction of NE-SW.

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