摘印地質彙報第二號

接觸變質中石榴子光性之研究

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接觸變質岩中石榴子石(Garnet)光性之研究

(南)

第一節 緒言

石灰岩每因受火成岩影響、產生接觸礦物、而石榴子石尤爲常見。一九一六年、地質研究所所長章鴻釗先生及礦物教授翁文灝先生、以浙江及安徽之石榴子石光性頗異、付蔭研究。自偏光顯微鏡 Polarization-microscope 下詳察其屈折差 Birefringence 之結果、疑爲一種斜方晶系 Orthorhombic system 之單體結合而成。

凡石榴子石採自石灰岩與火成岩接觸帶者、又皆有重屈折 Double refraction 之光性。如河南紅山石榴子石、其重屈折之光性更較複雜。當俟他日研究後、再詳述之。

一九二〇年董君常出示一種石榴子石鏡下影片、其光性略似上述二種。乃南京鎮江間龍潭銅山之產、由正長岩 Syenite 與石灰岩接觸而生。彼處亦有小鐵礦云。一九一九年、翁博士推想此種光性、係從一種特別情形而生、如中國接觸鐵礦中大都有之。茲以湖北及福建等處之石榴子石考之、而博士之言益信。故研究礦物之結晶、不第結晶學上甚有價値、即地質學上亦頗有關係也。茲先述產於浙江及安徽者。

第二節 浙江淳安縣之石榴子石

產地 此乃一九一六年鈕君翔青所採、云出淳安縣西鄉六都河村之沙中。嗣鈕君復親往調查、知爲一種石灰岩受火成岩作用變質而生、並將岩石標本寄附本所備核。

物理性質 石榴子石爲暗紫色之半透明體、中含細小雜質。堅而脆、斷口略現介殼狀。平均比重三·二一。剛度七·五。大小相若、其直徑約在半生的米突 (Cm.) 左右。有玻璃光澤。結晶爲斜方十二面體 Rhombic dodecahodron 如第一圖。

光性　按幾何學上對稱軸方向所磨製之薄片、在偏光顯微鏡下察之、爲數個多邊形相合而成、其狀態及排列之位置、皆按磨製之方向而異。述之如下。

（一）按幾何學上四對稱軸方向（即平行（100）面之方向）所磨製之薄片。若磨至集體中心點、或未至距中心點約二分之一者、爲四個二等邊三角形合之成一正方形。若未磨至集體中心點而已過距中心點二分之一者、則爲八邊形中分八個二等邊三角形、其大小由薄片之地位而異。若磨至距中心點約四分之一者、中爲八個等大之二等邊三角形。

第十一版第一圖、爲顯微鏡下之攝影、即八邊形中分八個二等邊三角形。從光性可分二類、每類爲二等邊三角形者四、交互相對。各消光二次、一則平行于八邊形之一邊、一乃垂直之。加用石膏薄片觀察之、其中一類有最大屈折率 Maximum index of refraction 與三角形之底邊平行、其餘一類則有中屈折率 Intermediate index of refraction 與底邊平行。詳察屈折差最大者、莫過於第十一版第一圖八邊形中之大三角形一類。換言之、即三角形之底邊接近斜方十二面體之長對角綫者是也。可知此類三角形中、既有長橢圓軸 Longest axis, γ, of indicatrix 平行於三角形底邊、且有短橢圓軸 Shortest axis, α, of indicatrix 垂直之。故可藉此以求長短二橢圓軸之較差也、其法用水晶切面平行於光軸者、與此石榴子石之四對稱方向同磨在一塊玻璃片上、以水晶楔 Quartz wedge 求所磨水晶色之次第 Order of the interference colour of the quartz 推算水晶之厚度、亦即石榴子石之厚度。再由此已知之厚度、及石榴子石光波之差度、Retardation of Garnet 算得此屈

折差爲〇·〇〇一二一。其餘一類二等邊三角形、則爲斜截橢圓體Indox-ellipsoid之面。有中橢圓軸 Middlo axis, β, of indicatrix 平行於此類三角形之底邊、底邊之垂線乃介於長橢圓軸與短橢圓軸之間者也。

(二)按幾何學上三對稱軸方向(即平行(111)面之方向)所磨製之薄片。若未磨至距集體中心之五分之四者、則外形爲等邊三角形、內分三個二等邊三角形。若磨過距集體中心之五分之四者、則外形爲六邊形、內分九個四邊形。若磨在中心時、外形仍爲六邊形、內分六個二等邊三角形。

第十一版第二圖、爲顯微鏡下之攝影、係六邊形內分九部者、三個不平行四邊形合之成一小六邊形、外繞六個較大之不平形四邊形、合成一大六邊形。此九個不平行四邊形、皆斜截橢圓體之面。其位置、顯與集體之軸成三對稱焉。中央之三個四邊形、各有橢圓軸二、適當四邊形之對角線。卽以其中三個長橢圓軸、爲三角形之三邊、而其分角線、卽集體之三對稱面也。外繞六個四邊形、其中較長之橢圓軸。按其投影之位置、皆與上述之三對稱面所成之角爲六十度。亦卽平行六邊形之一邊。

(三)按幾何學上二對稱軸方向(卽平行(110)面之方向)磨製薄片。倘磨在集體中心點時、爲六邊形、中分六個二等邊三角形。未磨至中心時、亦爲六邊形、但內分爲七區。

第十一版第三圖、顯微鏡下所攝、係六邊形內分爲七區者。各區之形、及排列位置、成二對稱。其中共分三類、四個不平行四邊形爲一類、二個二等邊三角形爲一類、中央一斜方復爲一類。其排列法、則四個不平行四邊形分居左右、互爲對稱、間以二等邊三角形、中央斜方形長對角線之二端、適與二個二等邊三角形之頂點相接、故顯成二對稱之形也。

論光性上之排列位置、亦頗合二對稱軸之方向。中央斜方形內之長對角線、與長橢圓軸合、其短對角線與中橢圓軸合、故求得長中二橢圓軸之較差爲〇·〇〇〇三一。又每二等邊三角形內有中橢圓軸平行三角形之底綫、換言之、卽平行集體之六邊形之一邊、短橢圓軸與中橢圓軸直角相交、故又求得中短二橢圓軸之差爲〇·〇〇〇九九二。二數相加、爲〇·〇〇一二三、卽爲屈折差。此與前法所求得之〇·〇〇一二一、相差甚微。其他不平行四邊形所截橢圓體皆係斜面。但其中較長橢圓軸各與對稱面所成之角爲三十度。

解釋　從上所述光性察之、顯每結晶、可假定由十二個斜方晶系之單體結合而成、實乃一集體也。單體內之橢圓體位置、其短橢圓軸垂直單體之斜方面。如圖二卽爲集體橢圓軸之球面投影圖、以（110）爲投射面者是也。集體（卽斜方十二面體）之面與橢圓體主截面之一平行、其長對角綫卽與長橢圓軸合。十二個單體皆爲錐體形、如第三圖、其斜方形之底面卽當集體之一面、集體之十二面卽十二個單體之底面也。其排列皆合等軸晶系之對稱法、故恒屬諸等軸結晶焉。茲以單體與集體之關係表之如下。

單體之長橢圓軸	合於集體之二對稱軸
單體之中橢圓軸	合於集體之四對稱軸
單體之短橢圓軸	合於集體之二對稱軸

第三節　安徽石榴子石之研究

產地　安徽繁昌縣長龍山、金石墩、大磕山、小磕山等處磁鐵鑛中有之。附近有花崗閃長岩。Grano-diorite

物理性質　繁昌石榴子石之種種物理性質、皆與淳產相同、惟爲偏菱形二十四面體。Icositetrahedron 如第

四圖。

光學性質　自各方面磨製薄片研究之、皆與淳縣石榴子石相同、惟爲帶狀組織 Zonal-texture 爲單屈折與重屈折二晶體互相間疊所致。如第十一版第四圖、爲其顯微鏡下四對軸方向之攝影。第十一版第五圖爲二對稱軸方向之攝影。

第四節　石榴子石之光學異性與外國所產之比較

十九世紀之初、光學異性之石榴子石、歐洲諸鑛物家雖有所見、尙無解釋。一八七六年、馬拉持 Mallard（參攷書1）始謂此種現象、乃數個對稱較低之晶體集合而成對稱較高之晶體耳。但其時諸鑛物家均非其說、德克郎 Klein（參攷書列2）及白老恩 Braun （參攷書3）二氏持之尤堅。謂此實等軸晶系、其光學異性、非因受壓力作用、即因化學性質關係、或爲同形異質之混合體 Isomorphous mixture 也。由安徽石榴子石各方面之觀察、似以馬拉特氏之學說爲近。更察產地之地質、足證石榴子石結晶後、並未受何種壓力、惟一種接觸變質之情形、可視爲重屈折結晶合成高對稱集體之唯一機會。故論其生成原因、當與熱液氣流、及由侵入岩所生之高熱、甚有關係也。

浙產石榴子石、僻倫泥司 Pyronoes 亦有之。馬拉特名之曰僻倫奈脫 Pyronoite 雷克絲厚克司 Lacroix（參攷書4）亦曾述及此種鑛物。繁昌所產、又與雷克絲厚克司（參攷書4）所述之阿潑隆姆類 Aplome type 相同、亦係單屈折係與重屈折系間疊而成。克郎氏所述之愛爾勃島 Elbe island 之八面體類、Octahedral type 及佛魯候 Wilui 之偏菱形二十四面體類、Icositetrahedral type 其八面體及偏菱形二十四面體之面、正與

僻倫奈脫之斜方十二面體之面相當。故安徽之偏菱形二十四面體、雖前未有人研究、參諸前說、亦與斜方十二面體甚相合也、

參攷書列左

1. Annals des mines X, 1876

2. Neues Jahrbuch für Minineralogie I, 87, 1883

3 Jablonowskish Gesell 1881

4 Minéralogie de France I, 213, 1893

ON THE OPTICIAL ANOMALIES OF SOME GARNETS PRODUCED BY CONTACT METARMORPHISM

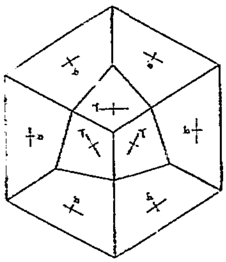
A.

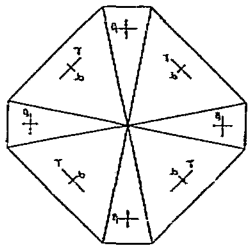
B.

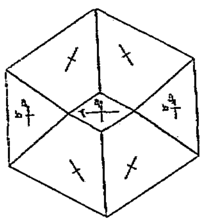
C.

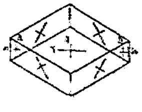
D.

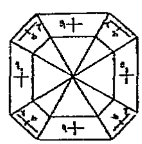
E.

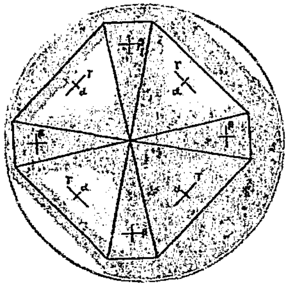




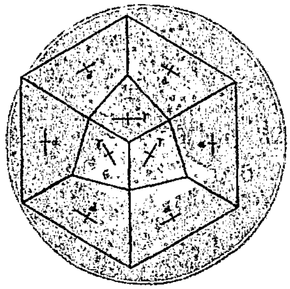








A.



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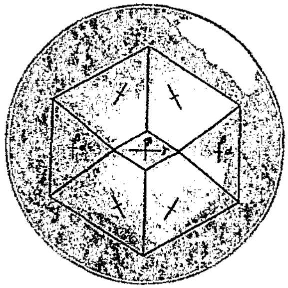

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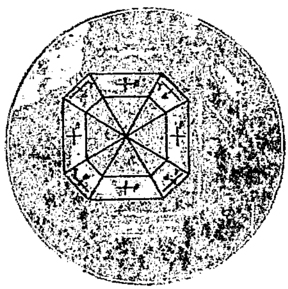

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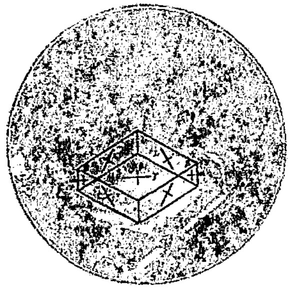

E.

from Elbe island an icositetrahedron type from Wilui in which each of the faces of the octahedron or *icositetrahedron corresponds to an elementary* individual instead of the rhombic dodecahedron as in the case of the pyreneite type. Our garnet from Anhwei, though having an icositetrahedron form belongs nevertheless optically to the rhombic dodecahedron type. It seems that this divergence between the geometrical form and optical property has not been observed in any of the birefringent garnets previously studied.

of the Chekiang garnet. Two sections respectively normal to the axis of tetragonal and the axis of binary are shown in plate XI. fig. D. and E.

OPTICAL THEORY AND COMPARISON WITH FOREIGN TYPES.

Early in the nineteenth century the birefringence of some calcic garnets was observed by several European mineralogists, but no explanation was offered. In 1876 Mallard[1] first proposed the explanation that it is caused by the combination of elementary individuals of a lower symmetry. Mineralogists were however not unanimous in adopting this view. Some German workers like Klein[2] and Braun[3], held that the garnet was really isotropic and the optical amomaly was due to the mechanical stress or isomorpous mixture. For the facts recorded in this paper, Mallard's theory seems to give, as far as we can see, the most satisfactory explanation. The geological condition of the deposits from which our garnets come seem to give no reason to suppose the existence of any particular pressure after the crystallisation. On the contrary, the special mode of origin of the contact metamorphism may provide particularly favourable condition to the crystallisation of the birefringent garnets and their association in higher symmetry. It may be assumed, for instance that the circulation of vapours orhot solutions and the great heat developed by the igneous intrusion are conditions favouring these phenomena.

The optical property of the garnet from Chekiang is very closely similar to the garnet from Pyrenees that Mallard described under the name of Pyreneite. Several similar cases have been described by Lacroix[4]. The garnet from Fan-Ch'ang Hsien, Anhwei, should be compared with the "aplome" type of Lacroix[4] which is characterized by alternating layers of monorefringent and birefringent garnet. Klein described an octahedral type

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1. Annales des Mines X. 1876.
2. Neues Jahrbuch für Mineralogie I, 87, 1883.
3. Jablonowskisch Gesell 1891.
4. Minéralogie de France I, 213, 1893.

The relation between the elementary individual and the compound crystal may be also summarized as following:

Three principal axes of indicatrix of the elementary crystal.	Coincide with	The axes of the geometrical form of the compound crystal.
γ	Coincide with	Axis of binary
β	Coincide with	Axis of tetragonal
α	Coincide with	Axis of binary

GARNET FROM FAN-CH'ANG DISTRICT, ANHWEI.

Mode of occurrence:– Crystals studied here were collected by Mr. H. T. Chang from the iron deposits of Chang-lung-shan (長龍山), Chin-shih-tun (金石墩), Ta-k'o-shan (大礚山), and Hsisao-k'o-shan (小礚山), in Fan-Ch'ang Hsien (繁昌縣). The deposits are of contact metamorphic origin, occurring between limestone and grano-diorite.

Physical properties:– All the physical properties are similar to those found in the garnets from Chekiang but the geometrical form is icositetrahedron as in fig. 4.

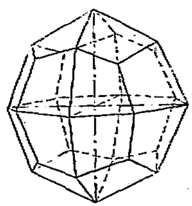

Fig. 4.
Icositetrahedron garnet.

Optical properties:– Though the geometrical form of the Fan-Ch'ang garnets is more complex, their optical properties are exactly the same as those of the garnet from Chekiang with the only difference that the crystals of Fan-Ch'ang show a zonal texture composed of alternating layers of optically isotropic, anisotropic crystals. Both the sections normal to the axis of tetragonal and binary have the same orientation as the corresponding sections of these sections has been determined to be $\beta-\alpha=.00099$. In combining the two determinations, we have the maximum birefringence for the crystal $\gamma-\alpha=.0013$ which differs only slightly from the value .00121 obtained from the section parallel to (100), Pl. XI Fig. A. Each of the four other portions is an inclined section of the index-ellipsoid. The longer axis of indicatrix makes on the average an angle of 30° with the symmetrical plane or 30° with ons side of its own trapezium which forms one side of the polygon of six sides symmetrically arranged about the symmetrical plan.

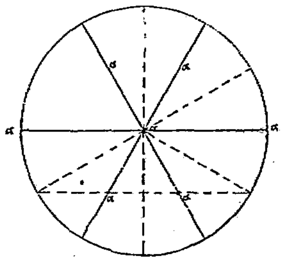

Fig. 2.

Spherical projection of the principal axes of the elementary indicatrix on the plane (110) of the compound crystals.

Explanation:- The apparently very variable properties above described will be quite comprehensible if we suppose that the crystal is built up by twelve elementary individuals of the orthorhombic system; and in each of the twelve elementary individuals the index-ellipsoid is arranged in such a way that the shortest axis, α, of indicatrix is perpendicular to each of the faces of the rhombohedron.

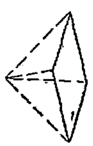

Fig. 3.
Elementary individual crystal.

This is represented by stereo-projection in fig. 2. Each face of the dodecahedron is therefore parallel to one of the three principal sections of the index-ellipsoid with the longest axis, γ, of indicatrix in the direction of the longer diagonal of the rhombus. Twelve individuals, in the form, of a pyramid as shown in fig. 3, with a base of rhombus forming face of the compound crystal, are associated symmetrically about the planes and axes which become planes and axes of symmetry for the compound crystal. From this mode of association results the optic properties studied above.

distance), or a hexagon divided into six portions (when the section passes through the centre).

Plate XI. fig. B. is a hexagon in which three inner portions are quadrilaterals and combine together to build up a polygon of six sides; the latter is again surrounded by six trapeze portions forming a hexagon. All nine portions are oblique sections of the individual index ellipsoid disposed symmetrically around the axis of trigonal. Each of the three central portions has two principal indeces of refraction coinciding with the the two diagonals of the quadrilateral so that the three maximum indices of refraction form the three sides of a triangle, the bisectors of which correspond to the three planes of symmetry. The axes of indicatrix of the outer six portions are inclined but their projections are arranged pair by pair symmetrically about the three planes of symmetry. In each of six portions the direction of the larger indices of refraction makes an angle of 60° with the plane of symmetry of crystal or parallels with the corresponding side of the hexagon (i. e. outer sides of the section of the compound crystal).

(c). Section normal to the axis of binary i. e. parallel to (110). The section appears as a polygon of six sides either composed of six isosceles triangles (if cut through the centre of the componnd crystal) or divided into seven portions (if it does not go through the centre).

The plate XI. fig. C. shows a section of a polygon of six sides divided optically into seven portions of which both the form and arrangement conform to the binary symmetry. The four portions, trapezia in form, are arranged in two pairs separated by two portions, isosceles triangles in form. A central portion is rhombic; its longer diagonal passes through the two vertices of the two isosceles triangles.

The optical orientation is arranged also in binary symmetry, for the axes of the indicatrix of the central portion are so arranged that the longest axis, γ, coincides with the longer diagonal of the rhombus, and the middle axis, β, with the shorter diagonal. The birefringence has been determined as $\gamma-\beta=$,00031. The axes of indicatrix of the two trianglar portions are so arranged that middle axis, β, is parallel to the base of the triangle, and the shortest axis, α, perpendicular to it in the same plane. The birefringence according to the position of the section. When it is cut at one fourth of the above mentioned distance the eight portions are almost equal in size.

The plate XI. fig. A. shows a octagonal section cut near the centre of the crystal. It contains eight portions: four form a group and alternate with the other four portions that form another group. Each portion has the same optical property as the one opposite. Each portion has its two extinction directions, one parallel, and the other normal to the octagonal side which serves as the base for it; but by the use of a gypsum plate it can be proved that the maximum index of refraction coincides with the direction parallel to the base of the triangle in one group of four portions, while in the four portions of the other group the corresponding base coincides with an intermediat index of refraction. As, on the other hand, the four larger triangular portions (i. e. those having as base the longer side of the octagon, or in other words, those passing near the longer diagonal of the dodecahedral face) show always the largest birefringence when compared with the other four portions as well as with sections of any other direction; it may be inferred that they must contain the longest axes γ aswell as the shortest one α of indicatrix of the elementary individuals. It is therefore possible to determine their birefringence.

So another section was cut normally to the axis of tetragonal i. e. parallel to (100) and prepared together with two sections of quartz parallel to its optic axis. From the interference colour of the latter and with the use of a quartz wedge, we determine the order of the interference colour of the garnet, hence its thickness; and then from the retardation and the known thickness of garnet the birefringence $(\gamma-\alpha)$ is calculated to be equal to .00121. The four portions of the other group are oblique sections of the index-ellipsoid with the external base of the triangle parallel to middle axes, β, of indicatrix and its normal intermediate between α and γ.

(b). Section normal to the axis of trigonal i. e. parallel to (111). This section shows either an equilateral triangle itself composed of three isosceles triangles (when the section cut further away from the centre than four fifth distance between the centre and the boundary of the compound crystal.), or a hexagon divided into nine portions (when the section cut not further away from the centre than four fifth of the above mentioned in sand formation from Ho-Ts'un (河 村) at west Ch'un-An Hsien (淳安縣). He wrote later that a personal investigation in the place showed that the crystals were really found in a metamorphosed limestone in a district where igneous intrusions were common. Specimens of rock sent to the Geological Survey confirmed his last statement.

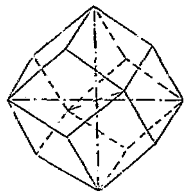

Fig. 1.
Rhombic dodecahedron garnet.

Physical properties:- The specimen is subtranslucent with dark spots and streations as inclusions. Though compact, it is very brittle showing subconchoidal or uneven fracture. The average specific gravity is 3.31 and hardness 7.5. Its diameter is half centimetre long or more. It has a vitreous luster and dark violet colour. Its geometrical symmetry is that of rhombic dodecahedron as in fig. 1.

Optical properties:- The mineral shows under the microscope a striking double refraction and appears as composed of a variable number of polygonal portions according to the direction of the thin section cut in the crystal. The following is a summary of the optical phenomena observed in sections cut normally to the different axes of the geometrical symmetry of the crystal.

(a). Section normal to the axis of tetragonal i. e. parallel to (100). This section shows a square composed of four isosceles triangles if cut through the centre or along any plane further away from the centre than one half distance between the centre and the boundary of the compound crystal. It will show a polygon of eight sides divided into eight portions in isosceles triangles when cut not further away from the centre than one half of the above mentioned distance; the size of the eight isosceles triangles are variable

ON THE OPTICAL ANOMALIES OF SOME GARNETS PRODUCED BY CONTACT METAMORPHISM.

BY T. I. LOO

INTRODUCTION.

Garnet is one of the commonest contact minerals produced by the metamorphism of limestone by igneous intrusions. A number of such crystals from Chekiang (浙 江) and Anhwei (安 徽) were studied by the writer in 1916 under the direction of Messrs. H. T. Chang (章鴻釗) and W. H. Wong (翁文灝) respectively director and professor of the Geological Institute at that time. The crystals showed always a certain birefringence under the polarization-microscope, which can be explained by the association of a number of individuals of orthorhombic symmetry. Since then garnets come from other localities but also in metamorphosed limestone have been examined and similar optic characters have been always found. Of these, the crystals from Hung-Shan, (紅 山) northern Honan, show even a more complex structure which I hope to be able to describe at a later date.

In 1920 Mr. C. Tung (董 常) kindly showed me micro-photos of a garnet from a small iron deposit of contact metamorphic origin from T'ung-Shan (銅 山) at Lung-T'an (龍 潭) between Chinkiang (鎮 江) and Nanking, (南 京) the same optic anomaly was still observed. Already in 1919 Dr. Wong suggested that this kind of optic anomaly was probably due to the special mode of origin of these contact formations which in China are often so rich in iron ores. Researches conducted on the garnets above mentioned and other ones from Hupeh (湖 北) and Fukien (福 建) seem to confirm this idea. The study of these crystals therefore is not only interesting from a crystallographic point of view but may have also an important geologic bearing. The following is the result of the study made in the garnets from the two first mentioned localities.

GARNET FROM CHUN-AN DISTRICT, CHEKIANG.

Mode of occurrence:– The specimens of garnet from Chekiang were collected by Mr. H. C. Niu (鈕翔青) in 1916 and were first stated to be found

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