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FOSSIL ARTHROPODS FROM ONYX-MARBLE

4. HOT CALCAREOUS WATERS KILLING INSECTS

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The article by John Hilton quoted in Note 1 of this series, suggested to the writer that perhaps the well now called Hot Mineral, in Imperial County, California, might furnish some ideas as to how insects become incorporated in onyx-marble.

On November 10, 1950, Dr. Raymond Jenness Barber and the writer visited Hot Mineral which is located near the All-American Canal Road, 37 miles southeast of Mecca, 4.5 miles easterly from Highway No. 111, turning in at the railroad stop Frink.

This well was drilled in 1939 under direction of the United States Reclamation Bureau. An official sign posted at the well states that it is 305 feet deep, with a 14 inch casing. A concrete block holds the pressure. The water flows at two cubic feet per second. It contains 4000 parts per million of dissolved salts, with CO_2 gas.

At the orifice the official temperature is 174°F. At five feet our measurement was 170°F. The mineral crystallizes out, forming pools of decreasing temperatures as the water flows down the slope. At about 75 feet from the orifice the temperature at the time of our visit was 158°F; at 150 feet it was 105°F; at about 300 feet it was 82°F; while the atmospheric temperature was 78°F.

The surface crystals are colored pink, yellow, blue, green, dark maroon, light brown, pure white, but mostly buff. Some of the colors are due to algæ living in the water. There are many little craters in the crystal bottom of the pools, caused by escaping gas.

Any object falling into the water becomes the center of crystallization. Thus a tiny insect may be the nucleus for a beautiful oval or circular floating disc, which grows concentrically, and under which other crystals form until the weight causes it to fall to the bottom. Stems become beautifully encrusted and the mineral replaces or modifies the tissues.

As expected we found that many insects are being killed by the hot water. They drift in the swiftly flowing water to the margins of the pools, and each becomes the center of crystal growth. Sometimes a thin paper-thick layer of crystals contains many tiny midges and other small insects. In all 132 specimens of arthropoda were found in the water in a short time. These represent Araneida, Odonata (Zygoptera and Anisoptera), Ephemerida, Psylloptera, Hemiptera (Corixidæ and Notonectidæ), Coleoptera (Hydrophilidæ, Staphylinidæ, and Psallidiidæ), Lepidoptera (Geometridæ), Hymenoptera (Vespidæ), and Diptera (Chironomidæ, etc); all winged except one spider.

The crystallization on these specimens is similar to that formed on the millipede *Parajulus lasti* Pierce, which was found among calcite and quartz crystals in volcanic lava at 900 feet depth in a well at Oxnard, California (See Bull. So. Cal. Acad. Sci. 44(1):2).

As hot water of 110° will kill almost any insect, it is probable that the bottom crust contains multitudes of them. These encrusted insects fall to the bottom as the crystal mass becomes too heavy to float, and there they are incorporated in the homologous mass of crystals, which in due time under proper temperature and pressure will become onyx-marble.

Thus we can say that the finding of winged insects in onyx-marble will indicate that they were caught in open flowing calcareous waters.

Word has been received that insect wings occur in the Mexican onyx-marble from El Marmol, Baja California. This deposit is formed by a hot mineral well on the side of a volcano, and the waters flowed into a depression where a solid deposit of onyx-marble is being mined.

Hot Mineral is on or near the San Andreas Fault.

5. FURTHER MATERIAL FROM THE BONNER ONYX-MARBLE QUARRY

In addition to the articles cited in part 1, Dr. Ralph V. Chamberlin described in 1949 (Trans. San Diego Soc. Nat. Hist. 11(7): 117-120, pl. 7) "A new fossil Chilopod from the Late Cenozoic." This specimen was classified in Order Geophilida, Geophilidæ new genus *Calciphilus*, new species *C. abboti*, a centipede with approximately 115 pairs of legs. The specimen was calculated to be 115 mm. long.

Clarifying the onyx-marble formation, Dr. Edwin D. McKee in 1946 published the article "Onyx marble in Northern Arizona" (Plateau, a Quarterly of Northern Arizona Society of Science and Art. Museum of Northern Arizona, Flagstaff 19(1):9-12, 4 figs.)

"The calcite has been deposited by water in cracks, such as joints and faults, and between sedimentary beds in Supai, Kaibab, and Moenkopi formations. At the Bonner Quarry southwest of Ashfork, the onyx-marble occurs in the Supai formation (Permian) which in the vicinity of the quarry consists of red shaly siltstone that has been dragged down along a large, nearly vertical fault. Movement of the fault has totaled some hundreds of feet, and has resulted in bending and shattering the rock in this area, thus allowing ample opportunity for water to penetrate and form onyx-marble. Deposition of the onyx-marble is largely, though not entirely along bedding planes in the red siltstone. Series of brown to honey yellow layers of calcite have formed, with each layer separated by a thin film of red detrital sediment that probably was dust accumulated during the time of non-deposition. The calcite layers have a tendency to thicken and dome upward toward their centers and individual layers commonly are progressively thinner and less massive toward the top of the series, ranging from four to five feet down to one to two inches. In many places the thin upper beds have been shattered since deposition."

"The fault is older than the basaltic lava on the adjoining hill, which it does not disturb."

Since writing the first three parts the writer has seen a total of 15 polished slabs of onyx-marble from the collection of Mr. J. W. Fisher of San Diego, President of the Southwest Onyx and Marble Company, and these contain 30 visible specimens, although some are too deep for study.

With the exception of one specimen, which may be wrongly interpreted, all of the species would normally be found in the soil or in damp crevices in the rocks, except perhaps at night, and it could be explained that they were caught by the seeping of the calcareous waters into their hiding places. This one doubtful specimen has the general form of a young walking stick, but with a longer head than usual, and it would not be unexpected if it should hide during the heat of the day in a crevice.

Of the total of 25 which can be ordinally classified, 15 specimens are pedipalpids, 1 is a millipede, 9 are insects. The insects belong to the Orders Dicellura, Rhabdura, Archæognatha, Zygentoma, and Phasmida. All in all it is a very primitive assemblage , without a single winged insect. Adding to these the specimens described by Petrunkevitch and Chamberlin, the total is 17 Pedipalpi, 1 Chilopoda, 1 Diplopoda, 9 Insecta.

Another characteristic of the entire series is that they have been boiled out by the hot calcareous water. In some specimens the dissipation of the body contents into the surrounding liquid is very evident. When viewed with a strong light, showing through, it is apparent that the remains are principally skeletal, and very much distended.

Only seven specimens (4 insects, 2 pedipalps, and the millipede were uninjured by the cutting and polishing. In addition there are several clumps of legs unassociated with bodies.

Mr. Louis Athon of the Los Angeles County Museum staff has made excellent photographs of these difficult subjects, which are valuable to supplement the records. These illustrate the graining of the onyx-marble, the diffusion of the body contents, and the injury resulting from cutting. The cutting was purely a commercial proposition, and the finding of the fossils was incidental.

Due to the condition of the material very little descriptive detail can be given, but drawings have been made to show such details as are clear and of value in locating the species.

The insects belong to groups seldom if ever found fossil, because of their delicate nature. This makes them very important. In fact few entomologists have taken the trouble to collect these rare earth-living insects.

6. A PERSONAL VISIT TO BONNER QUARRY

With Dr. Barber the writer visited the quarry from which the fossil arthropods were obtained. It is difficult of access, due to the very poor roads through a rocky juniper forest in the Kaibab National Forest of Yavapai Co., Arizona. It is located 17 miles southwest of Ash Fork in the NW ¼ of Section 21, Township 20 N (the South boundary of T 20 N is at 35° 00′ No. Lat.), Range 3 W (the East boundary of R 3 W is 112° W. Long.). Measured by aneroid barometer and checked with topographic sheets, the altitude is 5329 feet.

The formation containing the onyx-marble is Middle Permian, Supai formation, which has been faulted. Considerable onyx-marble is still in position, but the quarry was abandoned because of a serious cave-in.

The siltstone strata are inclined at an angle of 31° from the horizontal, in the direction of 10° East of true North. A layer of onyx-marble from 1 foot to 2.5 feet thick, interbedded at the same inclination, forms the roof of the open cavern, which extends to the depth of about 25 feet, with a width of about 15 feet.

Great piles of onyx-marble blocks lie around the quarry, where they were left by the operators. The material is so hard that it cannot be easily broken, and it is impossible to determine presence of insects in the rock without cutting and polishing.

We found evidences that this onyx-marble was formed by the infiltration upward and laterally in cracks and crevices, of hot, mineral-impregnated waters. In places where the crevices were not completely filled we found surface incrustations exactly similar to those at Hot Mineral. We found where hot waters had forced their way upward through the mushy top layer and flowed out over it to form new layers, in exactly the same manner as is now occurring at Hot Mineral. Pipes and gas tubes are still evident in the hard onyx-marble, and in one specimen the protruding mineral waters formed a bulbous mass of onyx-marble three inches in diameter protruding into the open, above a relatively smooth surface of the ancient rock-enclosed pool.

Several of the specimens show inclusions of angular fragments of the original red stone which indicate that the openings had probably been caused by movement and fracturing of the rock along a fault zone. This fault undoubtedly determined the position of the cañon in which the onyx-marble is now found, and caused the Permian siltstone on the Northeast side, and the Devonian limestone on the southwest side of the cañon, now to exist at the same elevation.

All of the insects and the other arthropods so far found in this onyx-marble are typical of arid-region rock-dwelling life, except the one phasmid, which might hide in the rocky crevices in the heat of day.

The evidence is that they were caught in the cracks by the hot water and instantly killed, and their body contents oozed into the surrounding waters.

Dr. McKee (1946) states in his article that the arthropod fossils "Probably represent a time when there was more water in the region than today to account for the extensive deposits in an area of present active erosion."

But perhaps a different interpretation can be given, considering Hot Mineral, El Marmol, and Bonner Quarry as parallel. The two first cases are in arid regions into which hot subterranean waters are being forced upward. At Hot Mineral the influence of this water is not shown outside of the area wet by the water, which in a few hundred yards has all sunk into the sandy soil or evaporated. So it appears that at Bonner Quarry hot mineral waters from below were forced up into the rocks and caught typically wingless, desert-rock-inhabiting creatures.

This new interpretation would merely push the time back to a period when subterranean volcanic activity was greater than now.

As to the age of the deposit, Dr. Barber wrote for our joint report: "the folding and faulting that caused the openings into which the calcareous waters flowed to form onyx-marble, might well have occurred during Mesozoic time when there was such widespread crustal unrest, resulting in the elevation of the Sierra Nevada and Rocky Mountains. The source of the hot calcareous waters, whether deep seated or not would probably have been associated with volcanic intrusions and extrusions, which occurred in all that part of the country during Tertiary times. The age of the onyx-marble may therefore be estimated at as much as fifty million years."

Dr. Barber's estimate would bring the fossils back to Eocene times. Dr. Rene Engel on examining the onyx-marble told the writer he was perfectly safe to put the age at least as early as the Miocene. So the age of the fossils lies between 12 and 50 million years. Dr. McKee places the onyx-marble as post-faulting, but earlier than the basaltic lava of the nearby hills.

The primitive nature of the fossils favors a considerable age. Probably some other factor will be found to give us a more accurate estimate of the period in which this deposit occurred.

7. THE FOSSIL PEDIPALPI FROM BONNER QUARRY

1951a

As was stated in part 5, the Pedipalpi are in the majority among the specimens found in the onyx-marble. Although most of them are defective in one way or another, it appears that the series includes at least three species, if reliance is to be placed on sternal characters.

The systematic position of these creatures is unquestionably in the Pedipalpi Latreille 1806, Uropygi Thorell 1882, because the cephalothorax is longer than broad, with almost parallel sides.

Kræpelin in 1899 (Das Tierreich, lief. 8:201-251, figs. 64-94) divided the Uropygi into two families, Thelyphonidæ Lucas 1835 with cephalothorax undivided, and cauda segmented; and Schizonotidæ Thorell 1888, with cephalothorax divided between second and third pairs of legs; cauda unsegmented.

Petrunkevitch 1945 following Hansen and Soerensen 1905 altered Schizonotidæ to Schizomidæ, and raised it to the ordinal rank as Schizomida, adding the family Calcitronidæ for his fossil insect, with three caudal segments. The writer does not feel that the creation of an order is warranted, but would still consider Pedipalpi as an order, Uropygi as a suborder, and create Schizomoidea and Thelyphonoidea as new superfamilies, in line with modern classification.

Even then it becomes difficult to classify these fossils, because we cannot see all necessary characters, and those we can see appear to be intermediate between the two groups. The solution for the present is to simplify group characters and place a different stress upon them.

1a. Caudal appendage long, many-segmented; tarsal flagellum of first pair of legs 9-segmented; cephalothorax undivided..........
..................THELYPHONOIDEA new superfamily............
..................THELYPHONIDÆ Lucas 1835
This group contains at least 10 genera.

1b. Caudal appendage short, with one or few segments.................
..................SCHIZOMOIDEA new superfamily..................2.

2a. Caudal appendage short, with few segments; fourth trochanter longer than coxa; fossil species...
..................CALCITRONIDÆ Petrunkevitch 1945...........3.

2b. Caudal appendage short, unsegmented, or with a thick end knob; fourth trochanter shorter than coxa..............................
..................SCHIZOMIDÆ Hansen and Soerensen 1905....4.

3a. Caudal appendage 7-segmented; tarsal flagellum of first pair of legs with metatarsus and three tarsal joints; second, third, and fourth pairs with metatarsus and two tarsal joints; second and third coxæ very narrowly separated, almost contiguous, but fourth coxæ well separated. ONYCHOTHELYPHONUS Pierce 1950.

b. Caudal appendage 3-segmented; tarsal flagellum of first pair of legs with metatarsus and seven tarsal joints; second pair with five tarsal joints; third and fourth pairs with four tarsal joints; second and third coxæ very narrowly separated; fourth coxæ contiguous ....
..................CALCITRO Petrunkevitch 1945.

4a. Fossil species. Second, third and fourth coxæ broadly separated; pedipalpi simple, untoothed....CALCOSCHIZOMUS new genus.

b. Living species; tarsal flagellum of first pair of legs with metatarsus and seven tarsal joints; second, third and fourth legs with three tarsal joints; pedipalpi toothed on one or more segments..................SCHIZOMUS Cook 1899.

(*Schizonotus* Thorell 1888 preoccupied)

..................TRITHYREUS Kræpelin 1899.

(*Tripeltis* Thorell 1889 preoccupied).

..................STENOCHRUS Chamberlin 1922.

The difficulty in classification of the fossils lies in the disintegration that has obscured characters. In two specimens, BQ 8 and BQ 11, assigned to *Calcitro fisheri* Petrunkevitch, the cephalothorax is definitely transversely divided between the second and third pairs of legs. In no other specimen is such a division indicated. Specimen BQ 15, measuring 4.0 mm. in length, may be *Calcitro fisheri,* but the dorsal view (Figure 5) does not show any division of the cephalothorax, and the cauda seems undivided, as in *Schizomus*.

The division of the tarsi into segments cannot be definitely determined in BQ 20, which is named *Calcoschizomus latisternum.*

In size, the three species before the writer range as follows: *Onychothelyphonus bonneri* 3.64 *mm.; Calcitro fisheri* 4.5 mm. (BQ 8), 4.4 mm. (BQ 13), 4.75 mm. (BQ 11), 4.8 mm. (BQ 17), the type measured 4.4 mm.; and the paratype 4.0 mm.; and *Calcoschizomus latisternum* 14 mm. Two undeterminable specimens should be mentioned: BQ 14 with front end missing is 6.16 mm. long; and BQ 27 in side view, the pedipalpi missing, broken between third and fourth pairs of legs, is 13 mm. long.

In addition to all of these specimens are three tiny ones too deep for exact characterization, but unquestionably pedipalpids. They may be young. No division of thorax is evident, nor is any cauda. They measure 2.0, 2.6, and 3.0 mm. in length. Perhaps at a later date the plaques can be polished down to make description possible.

Mr. Louis Athon, Los Angeles County Museum photographer, has photographed these difficult subjects, and on plate 1 are represented the three named species. Figure 3 is of value only to show the crystalline nature of the onyx-marble, and the difficulty of determining characters. Figure 4 shows the disintegration of the tissues which took place in the hot calcareous water before final crystallization.

The sternum gives the best character for differentiating the species at hand. Petrunkevitch figured *Calcitro fisheri* with fourth coxæ in contact, second and third narrowly separated. The specimen BQ 8 fits the drawings and description in every respect except that the fourth coxæ are as widely separated as the second, and not in contact (Figure 6).

In Article 3, *Onychothelyphonus bonneri* was illustrated, and it will be noted that the fourth coxæ are widely separated, while second and third are very narrowly separated.

The new species now to be described differs from both by having all coxæ widely separated, as shown in Figure 7.

CALCOSCHIZOMUS, new genus.

Pedipalpids of the family Schizomidæ; with simple, untoothed pedipalpi; cauda simple unsegmented; all coxæ well separated; fourth trochanters shorter than the coxæ.

CALCOSCHIZOMUS LATISTERNUM, new species. (Figures 4, 7)

Type of the genus. Fossil in onyx-marble from Bonner Quarry, Kaibab National Forest, Yavapai County, Arizona. Found by J. W. Fisher.

Length of body 14 mm. The left pedipalp is distinctly outlined, without tooth or prominence, but segmentation is not clear. A very hairy process from near base of this pedipalp is probably the chelicera. Between the front coxæ there is a round elevation. The coxæ are all well separated; the trochanters all shorter than the coxæ. On account of the dense clouding around the legs, it is not possible to accurately define the legs.

1951b

8. A FOSSIL MILLIPEDE FROM BONNER QUARRY

A beautiful specimen of millipede is on circular slab No. 10. The front portion was separated from the remainder of the body, a short distance. In the slab the hind end is too deep for diagnostic characters.

DIPLOPODA Blainville & Gervais 1844

JULOIDEA Attems 1898 (*Iuloidea* Silvestri 1896)

PARAJULIDÆ Attems 1909

PARAJULUS Humbert & Saussure 1869

PARAJULUS ONYCHIS, new species. (Figures 8, 9, and Plate 16)

Fossil in onyx-marble, Bonner Quarry, Kaibab National Forest, Yavapai County, Arizona. Found by J. W. Fisher.

Length of curled specimen 18 mm.; approximate length of body 39.4 mm. Number of segments: head, 4 thoracic, 54 abdominal, 1 terminal,—total 60 segments. Number of legs: 3 thoracic pairs (none on third segment), 108 abdominal pairs,—total 111 pairs. One 5-jointed antenna has been separated from head. The left first thoracic leg (Figure 8) is greatly enlarged and five-jointed, but a detached claw may belong to it, making it 6-jointed. The abdominal legs (Figure 9), two pairs to a segment, are 6-jointed.

Fig. 1

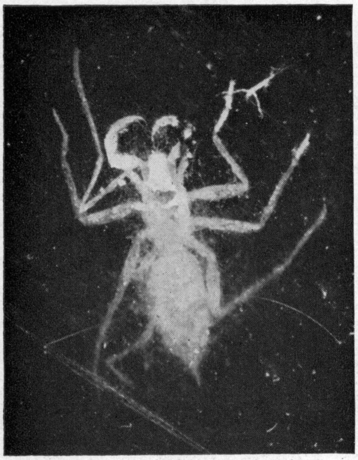


Fig. 2

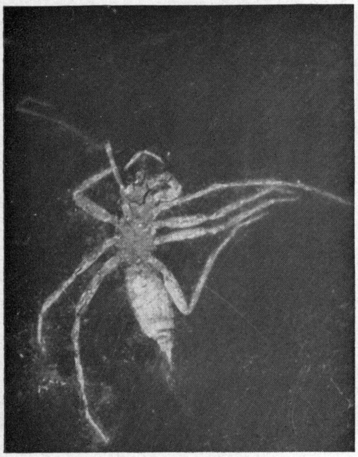


Fig. 3

Fig. 4

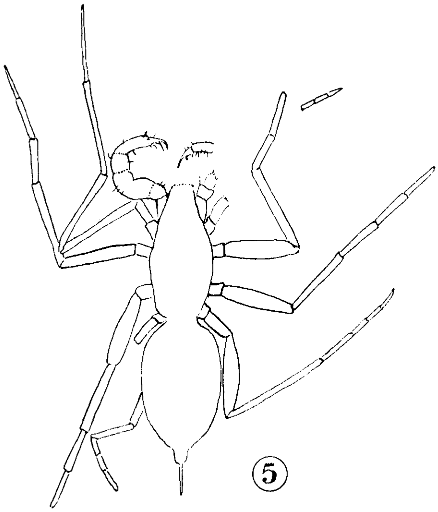
PLATE 14

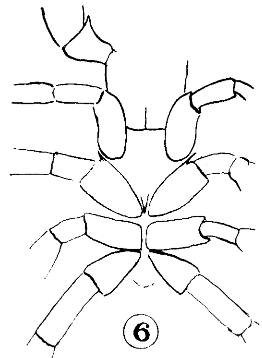
Figure 1. *Calcitro fisheri Petrunkevitch* (Specimen BQ 15), length 4 mm.

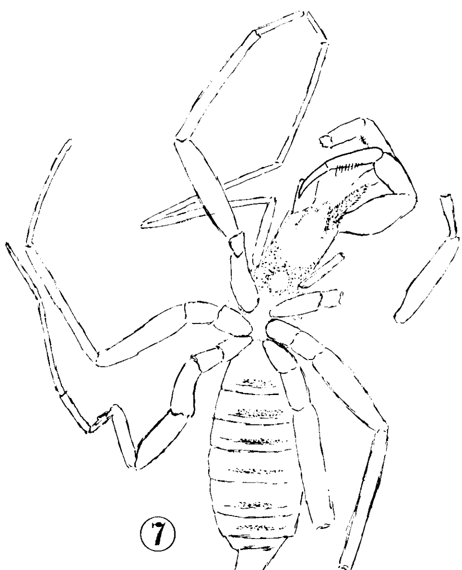
Figure 2. *Calcitro fisheri* Petrunkevitch (Specimen BQ 13), length 4.4 mm.

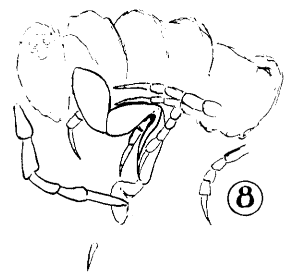
Figure 3. *Onychothelyphonus bonneri* Pierce (Specimen BQ 1), length 3.64 mm.

Figure 4. *Calcoschizomus latisternum* Pierce (Specimen BQ 20), length 14 mm.









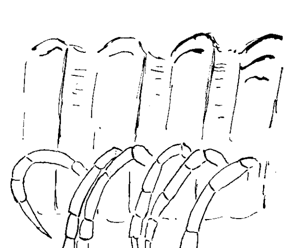


PLATE 15

Figure 5. *Calcitro fisheri* Petrunkevitch (Specimen BQ 15), detail.
Figure 6. *Calcitro fisheri* Petrunkevitch (Specimen BQ 8), detail of sternum.
Figure 7. *Calcoschizomus latisternum* Pierce, detail study.
Figure 8. *Parajulus onychis* Pierce, detail of anterior portion.
Figure 9. *Parajulus onychis* Pierce, detail of three abdominal segments.