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SOLUTION TO THE *HALLOPUS* ENIGMA?

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ABSTRACT. For some unknown reason, the original source of the still unique type specimen (YPM 1914) of the fossil reptile *Hallopus victor* was never revealed by its author, O. C. Marsh (1877). Whether out of ignorance or by deliberate design, Marsh never revealed either the geographic locality or the stratigraphic provenance of this specimen despite (or because of) the importance he apparently attached to it. Past attempts to locate and date its source have been unconvincing. Here, we submit a probable resolution to this century-long enigma.

INTRODUCTION

A century ago, *Hallopus victor* was a very familiar binomial. At times, it occupied a prominent position, central in the thoughts of knowledgeable 19th-century systematists and taxonomists, those scholars actively concerned with the ordering and classifying of ancient and modern life forms. *Hallopus* became important because of the identity of its author, O. C. Marsh, and because neither its systematic identity nor its stratigraphic origin were ever satisfactorily resolved during Marsh's life time. Moreover, the exact locality was never agreed upon, despite seemingly reliable, if not irrefutable testimony by one of Marsh's most dependable collectors, David Baldwin. The stratigraphic occurrence is still in dispute.

Together, all these uncertainties would seem to be more than sufficient reasons for dismissing this taxon at once. Yet *Hallopus* is an historically important taxon which has vexed many scholars (some of them very prominent) over the years. The systematic position and its phyletic relationships appear to be resolved now, thanks to the studies by A. D. Walker (1970). Walker concluded that the incomplete skeletal fragments (parts of the pelvis, hind leg, and vertebral column) represent a primitive crocodilomorph. That assignment is now widely accepted (see Carroll, 1988. p. 620). The stratigraphic dispute may also be near resolution, contrary to Norell and Storrs (1989), depending on how this contribution is received.

HISTORY OF THE SPECIMEN

During the spring of 1877, Marsh learned from one of his collectors (David Baldwin) about the discovery of a fossil "bird" specimen found at

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Garden Park near Cañon City, Colorado. Ultimately, Baldwin secured the specimen and sent it to Marsh, where it was accessioned and entered into the Peabody Museum collection. In September of 1877, Marsh described the specimen in this journal, as a "very small dinosaur" which he designated *Nanosaurus victor* (Marsh, 1877). (A second specimen, purportedly from the same strata, was later found by a different collector, O. W. Lucas; in the same paper of 1877, Marsh described and named this specimen *Nanosaurus agilis.* Even though often mentioned together in subsequent records, it has never been established that the two specimens were found at the same time or—place. The *N. victor* specimen was sent to Marsh at Yale by David Baldwin where it was received at Yale and accessioned on May 8, 1877 as number 958. The *N. agilis* specimen was sent to Marsh by O. W. Lucas, where it was received on August 24, 1877 and accessioned as number 1000).

Marsh (1881) later removed the first specimen (*N. victor*) from *Nanosaurus* and placed it in his new genus *Hallopus,* noting the distinctive form of the calcaneum that seemed to indicate "a foot especially adapted for leaping," hence the name *Hallopus. Hallopus victor* became the type of a new family Hallopodidae and the key basis for a new dinosaurian suborder, Hallopoda.

Marsh seems never to have doubted the affinity with the Dinosauria, although it does appear that he questioned the proximity of that relationship (1890) when he concluded that "the Hallopoda at present may be regarded as an order of Dinosauria standing more apart from typical forms than any other." By 1895 and 1896, though, he considered *Hallopus* to be a real link between typical dinosaurs with a "true dinosaurian pelvis" and the more primitive pseudosuchians that featured a primitive calcaneum. There, he retained *Hallopus* in the Suborder Hallopoda, which he included in his dinosaurian Order Theropoda.

Hallopus remained grouped with the "Dinosauria" for the next three quarters of a century, although always in an uncertain or doubtful position. Starting with Marsh's original description (1877) of the specimen, briefly alluding to "a small dinosaur," and his more proper description (1890) of the (still) unique specimen (now YPM 1914), *Hallopus* has been an unsettling focal point until A. D. Walker (1970) came forward with the (now obvious) resolution. In 1896, Marsh firmly established its dinosaurian "identity," which was repeated by von Huene and Lull (1908) and by von Huene (1914), where *Hallopus* was considered a primitive coelurosaur close to the Pseudosuchia. Romer (1956) first placed it with *Procompsognathus* in the Family Hallopodidae but later (1966) included it in the Family Coeluridae, with some reservation. That last assignment may have been influenced by the earlier conclusion of DeLapparent and Lavocat (1955) who allied the genus with *Compsognathus* in their Family Compsognathidae.

In spite of the calcaneal clue recognized by Marsh, the very incomplete and largely disarticulated skeletal remains of the type specimen (YPM 1914) were not correctly identified until Walker's (1970) thorough reanalysis, in comparison with other primitive thecodontians. The true systematic position of *Hallopus* as a crocodilomorph became apparent. That long-delayed and obfuscated placement resulted as much from the incomplete anatomical evidence available as it did from the slowly evolving recognition of archosaurian systematics and phylogeny. That systematic position was further obscured by the unknown stratigraphic origin of *Hallopus* (and the failure to discover any other example).

HISTORY OF THE *HALLOPUS BEDS* QUANDARY

In 1891 (p. 337), Marsh proposed the term "*Hallopus* Beds":

> Near the base of the Jurassic a new horizon may now be defined as the *Hallopus* beds, as here alone remains of the remarkable reptile named by the author *Hallopus victor* have been found. Another diminutive dinosaur, *Nanosaurus,* occurs in the same strata. The horizon is believed to be lower than the *Baptanodon* beds, though the two have not been found together. The *Hallopus* beds now known are in Colorado, below the *Atlantosaurus* beds, but quite distinct from them.
>
> The *Baptonodon* beds have been found in many localities everywhere beneath the *Atlantosaurus* beds, and having below them, at various localities, a series of red beds, which may, perhaps, contain the *Hallopus* horizon, but are generally regarded as Triassic.

After this, it was stated several times (Williston, 1905; Schuchert, 1939) that Marsh apparently was never certain of the exact stratigraphic level of the type specimen of *Hallopus victor* (YPM 1914) or that of *Nanosaurus agilis* (YPM 1913), although he apparently did come to the belief that the source was Triassic or lowermost Morrison Formation (=Jurassic). He remained reticent about revealing the actual locality, if indeed, he ever *really* knew. It is known (from an April 30, 1877, letter to Marsh) that the specimen of *Hallopus* was obtained by David Baldwin, who purchased it for the price of $3.00 from an unidentified man at a "curiosity shop" in Colorado Springs (Schuchert, 1938, p. 21). The specimen was collected by a John Jennings of Cañon City and a S. C. Robinson of Colorado Springs. It was reported to have been "found eight miles north of Cañon City on the west side of Four Mile Creek, about three miles above oil wells, half a mile west of Mr. Felch's house" (Schuchert, 1939, p. 20–21). The site was located "On the north side and about 30 feet below the top of a low red point, north of first table-topped hill west of Mr. Felch's house." In a later letter, Baldwin wrote "The two little red slabs from the Jura that I sent you a year ago came from a stratum of solid red rock just underneath those large bones[1] that Lucas found. There is a little knoll or tent-shaped point around which Lucas worked and the (bird) bones came from the solid red strata about fifteen feet below the apex of the cone and on the north eastern side."

These details from Baldwin to Marsh, theoretically, should have removed any uncertainty in Marsh's mind about the actual stratigraphic source of the *Hallopus* "bird" bones, especially since this information

[1] Reference to the *Camarasaurus supremus* holotype specimen (AMNH 5760) obtained for E. D. Cope in 1877 at Garden Park.

came to Marsh in 1878—more than two years before Marsh himself visited Cañon City in 1880. Schuchert (1939, p. 22) remarked that the words "tent-shaped point" has special significance in that it probably was in reference to a "place known locally as the Nipple." "It is also known that much of Lucas' collecting in 1877 was in chocolate-colored beds in the upper part of the Morrison formation, from which he dug out the skeleton of the great dinosaur *Camarasaurus supremus*" (Schuchert, 1939, p. 22).

In his 1877 description of *Nanosaurus* (=*Hallopus*) *victor* and *Nanosaurus agilis,* Marsh indicated that the horizon was said to be "probable Jurassic, but possibly in the lower part of the Dakota Group, thus possibly early Cretaceous, and the locality was simply given as the 'Rocky Mountains'." In his 1881 paper, the locality was reported as "Colorado." Also, in 1881, the stratigraphic horizon that produced *Hallopus* (and supposedly, *Nanosaurus agilis*) was changed to "Lower Jurassic or Upper Triassic" (Marsh, 1891). As Schuchert (1939, p. 21) suggested, Marsh may have been more impressed by the color of the rock, which he equated with the much lower Triassic strata, than he was by Baldwin's precise locality data. Schuchert and Williston before him had not known of the red strata high in the Morrison beds at Garden Park, and Marsh apparently did not either.

The stratigraphic dispute became throughly confused when Marsh (1891) designated a sequence of strata low in the Mesozoic section of America as the *Hallopus* beds, declared by him (1891) to be the source of *Hallopus* (and presumably of *Nanosaurus*) at the *base* of the Jurassic. The *Hallopus* beds were thus defined as occurring beneath the *Atlantosaurus* beds *and* the *Baptanodon* (= Sundance Formation ±) beds but above the *Otozoum* or Connecticut River beds (=Triassic), according to Marsh (1891). The issue became even more confusing when Williston (1905, p. 338-339) wrote:

> The precise spot whence the specimen came was pointed out to me, the base of an escarpment of red sandstone, whither the specimen had fallen from the overhanging cliff. Its precise horizon in the cliff was never ascertained, though the block of red sandstone in which the fossil was inclosed left no doubt to its derivation. This peculiar character of the matrix, so different from anything found in the Atlantosaurus beds, has been mentioned by Marsh, though he never gave definite information as to the location of the discovery.

(This statement by Williston was in reference to "the type specimen of *Hallopus victor* was discovered (sic) by M. P. Felch in August, 1877, in Garden Park, near Cañon City, Colo., a few weeks before the time of my first visit to that since famous locality" (Williston, 1905, p. 338).

Williston errs in the above quote: the specimen was *not* found by M. P. Felch, and it was *not* found in August of 1877, because it had already been accessioned at Yale Peabody Museum as number 985 on May 8, 1877, and Baldwin had written Marsh about this "bird" specimen as early as April 30, 1877. Obviously, the Felch family had many members, but there can be no confusion that the site visited by Williston, after the fact, cannot have been the actual site from which John Jennings and S. C.

Robinson obtained the type specimen of *Hallopus*. Williston continues: "The type specimens, as Marsh has said, came from a horizon far below the lowermost of those yielding sauropodous remains. Hatcher has said that "no fossils have been obtained from the Red Beds of Garden Park"—an error" (Williston, 1905, p. 341).

With these facts in mind, it is now very doubtful how much weight can be given to Williston's "validation" of Marsh's original designation of the *Hallopus* beds. For instance Williston (1905, p. 338) stated emphatically:

> I am now in a position, I believe, to show that the horizon (*Hallopus* beds) is a distinct one, and it belongs, *not to the Lower Jurassic, but to the Upper Triassic.* (Emphasis by the present authors.)

NEW EVIDENCE

In 1991, the Denver Museum of Natural History began an extensive study of the Morrison Formation in the Garden Park area just north of Cañon City, Colorado. One of the goals was to relocate all vertebrate and invertebrate fossil localities on behalf of the Bureau of Land Management and the Garden Park Paleontological Society. This included locating old quarries as well as locating and developing new ones. Copies of Cope's field notes and map made during his 1879 visit and copies of the accession records from the Yale Peabody Museum were used to locate old quarries.

Several test excavations were made at three of the Cope quarries around the base of the Nipple in June, 1991. These quarries were in a brownish-red mudstone overlying a ledge-producing reddish-brown sandstone (fig. 1A). It was from the Peabody Museum accession records for 1877 that the locality of *Hallopus* was identified as being the ledge-producing sandstone below the Cope Quarries. A hand sample was collected from this sandstone for the petrographic analysis (see below) and comparison with the *Hallopus victor* matrix (see fig. 1A).

The Morrison Formation in the Colorado Plateau has yielded radiometric dates of 154.9 ± 1.5 Ma near the base and 145.2 ± 1.2 to 149.4 ± 0.7 Ma near the top (Peterson 1992). Thus the Morrison is late Oxfordian to early Tithonian in age.

The Morrison Formation is subdivided in several members on the Colorado Plateau. In the Garden Park area it is only informally divided into an upper and lower member (see fig. 2). The lower member is characterized by numerous sheet sandstones separated by light green and light gray mudstones with numerous freshwater limestones. The upper member is characterized by the predominance of reddish mudstone and few tabular sandstones. The sandstone containing the Marsh Quarry can be traced almost without interuption to below Cope's Nipple.

The entire sequence of the Morrison Formation is exposed in the vicinity of the Nipple. The base is placed immediately above the reddish-orange sandstone of the Ralston Creek Formation (Peterson, personal communication). This contact is almost 18 m lower than as placed by

Fig. 1(A) View toward the east showing Cope's Nipple and the "*Hallopus* sandstone" (arrow). One of Cope's *Camarasaurus* quarries, that of the holotype of *Camarasaurus*, is on the bench to the right of the Nipple. About two-thirds of the Morrison Formation is visible in the photograph. The "Marsh-Felch Quarry Sandstone" is visible just above the dead branch in lower left corner of the photograph. Part of the measured section was made on the slope below Cope's Nipple.

(B) View toward the north showing the "*Hallopus* sandstone." Sample for analysis was taken about where the person is standing (to the left of the tree).

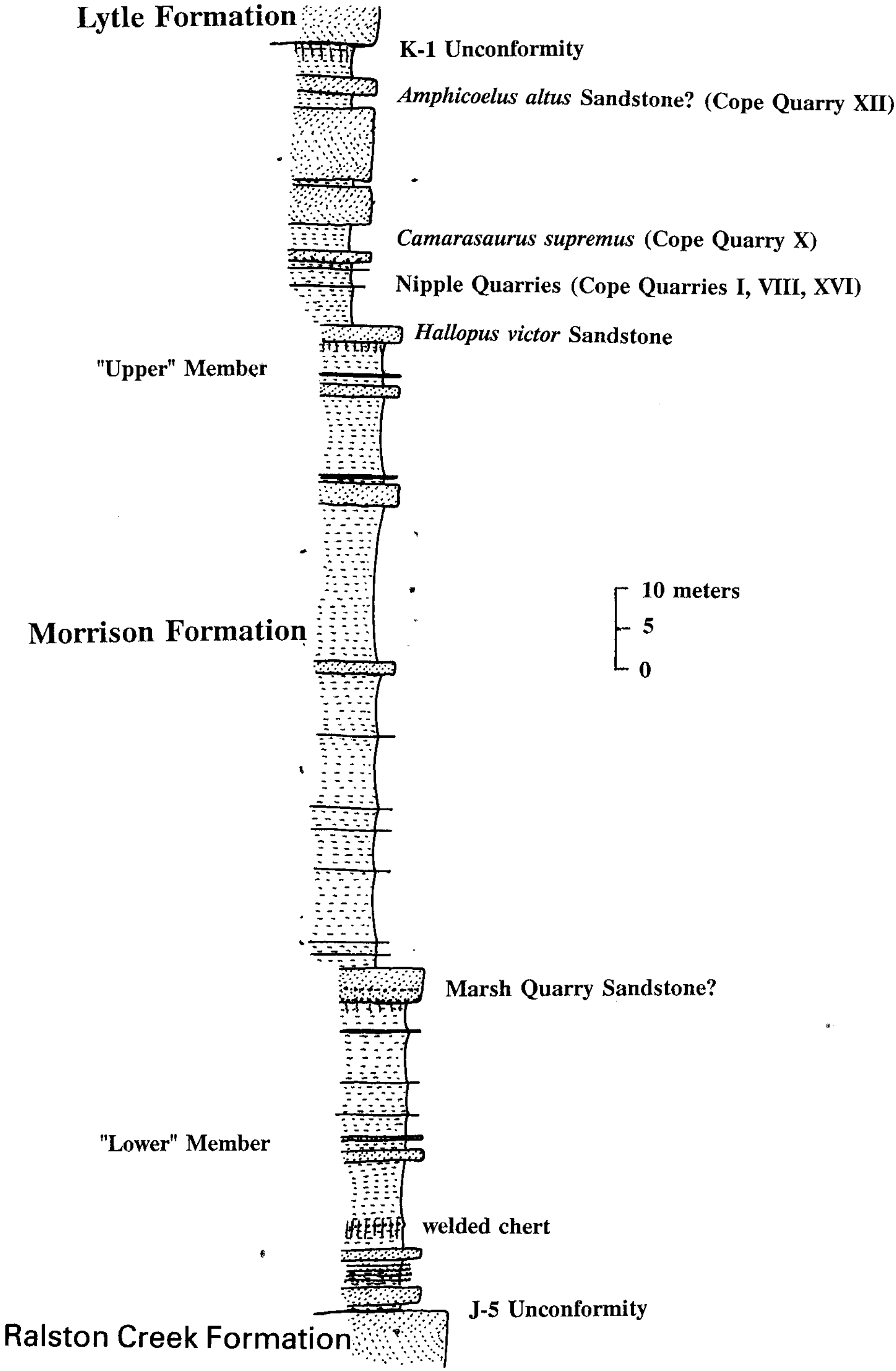

Fig. 2. Stratigraphic column near Cope's Nipple, W 1/2, NE 1/4, sec. 28, T.17S., R.70W. Cooper Mountain Quadrangle. The three major ledge producers are the *Hallopus* sandstone, the Marsh Quarry sandstone (?), and the top of the Wanakah Formation. The thin resistant beds immediately above the Marsh Quarry Sandstone (?) are lacustrine limestones.

TABLE 1
Modal analyses

	1914	1914-1
Quartz	39	26
K-Feldspar	12	12
Mica	2	4
Plagioclase	1	1
Hematite	2	2
Kaolinite	7	10
Tourmaline	tr.	tr.
Ferruginous Matrix	30	39
Calcite Matrix	7	5

Notes: tr. = trace. Modes do not include lithic fragments. Lithic fragments make up ~3 and ~1 percent of samples 1914 and 1914-1, respectively.

Hassinger (1959) or Brady (ms and 1969). The upper contact is placed at the base of a massive yellow-weathering sandstone overlying a purple paleosol with prismatic columnar structure (Peterson, personal communication). This contact is about 30 m higher than that of Cross (1894), Hatcher (1901), Mook (1916), Osborn and Mook (1921), Hassinger (1959), and Brady (1967, 1969). Placing the upper boundary so much higher places what may be Cope's *Amphicoelus altus* quarry about 4 m below the Lytle Sandstone. This is more in keeping with Cope's field notes.

COMPARATIVE PETROGRAPHIC ANALYSIS

Methods

Petrographic and geochemical analyses were done on polished thin sections of sandstone cut from the *Hallopus* type specimen (YPM 1914) and the hand sample collected from the base of the Nipple in June, 1991 (YPM 1914-1) (figs. 1 and 2). Mineral composition determinations and backscattered electron images were obtained using the JEOL JXA-8600 microprobe at Yale University. Quantitative wavelength-dispersive spectrometer (WDS) analysis of K-feldspar was done using natural and synthetic standards, off-peak background corrections, and ZAF matrix corrections. Accelerating voltage and beam current were 15 kV and 20 nA, respectively. Seven "spot" analyses of K-feldspar were performed for each sample. Because the K-feldspars are cryptoperthites (see below), a defocused beam (20 micrometer diam) was used in order to obtain spatially averaged compositions. Energy-dispersive spectrometer (EDS) analysis was used for mineral identification and general assessment of mineral chemistry. Modal analyses were done using a computer-automated microscope stage in conjunction with the line-integration method (Brimhall, 1979; Ague and Brimhall, 1988). The automated microscope stage was also used to measure average grain sizes in thin section.

General Description and Modal Mineralogy

Samples 1914 and 1914-1 are brick-red, fine-grained sandstones which appear identical to each other in hand specimen. Petrographic analysis indicates that both rocks contain the same suite of detrital minerals and matrix materials (table 1). The samples are rather poorly sorted and consist predominantly of quartz, K-fieldpar, and kaolin-type clays set in a dark ferruginous matrix (figs. 3, 4, and 5). The ferruginous matrix is responsible for coloring hand samples brick-red. The modes for the two samples are similar, although 1914 has a somewhat higher quartz/matrix ratio than does 1914-1 (table 1). "Arkosic wacke" is the appropriate rock name for the samples, in view of their substantial K-feldspar and matrix content (Pettijohn, 1975, p. 214).

Petrography

Quartz.—Quartz occurs as subangular to subrounded clasts; grain sizes for samples 1914 and 1914-1 are 150 to 200 and 100 to 150 micrometers, respectively (figs. 4 and 5). Textures indicative of intracrystalline deformation, such as undulose extinction, are absent, and polycrystalline grains are extremely rare.

K-feldspar.—Both samples contain subangular to subrounded, untwinned K-feldspar grains relatively free of clay alteration products (figs. 4 and 5). Average grain sizes for samples 1914 and 1914-1 are about 150 and 100 micrometers, respectively. Backscattered electron imaging reveals that the K-feldspars are cryptoperthites containing isolated, about 1 micrometer long exsolution "blebs" of a more sodic feldspar.

Kaolinite group minerals.—Kaolinite group minerals occur as: (1) fairly large (50-200 micrometer long) equant to elongate aggregates of crystals (fig. 5), (2) alteration products on the margins of feldspar and

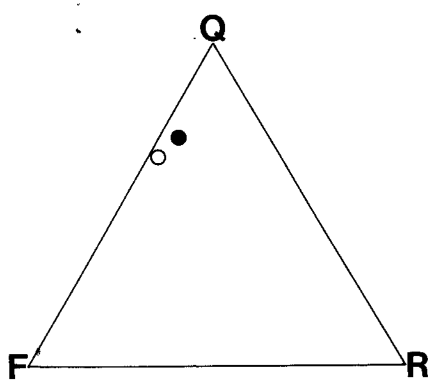

Fig. 3. Proportions of total quartz (Q), total feldspar (F), and total rock (lithic) fragments (R). Modal mineralogy is consistent with a continental block provenance (Dickinson and Suczek, 1979). Samples 1914 and 1914-1 are indicated by the filled and open circles, respectively.

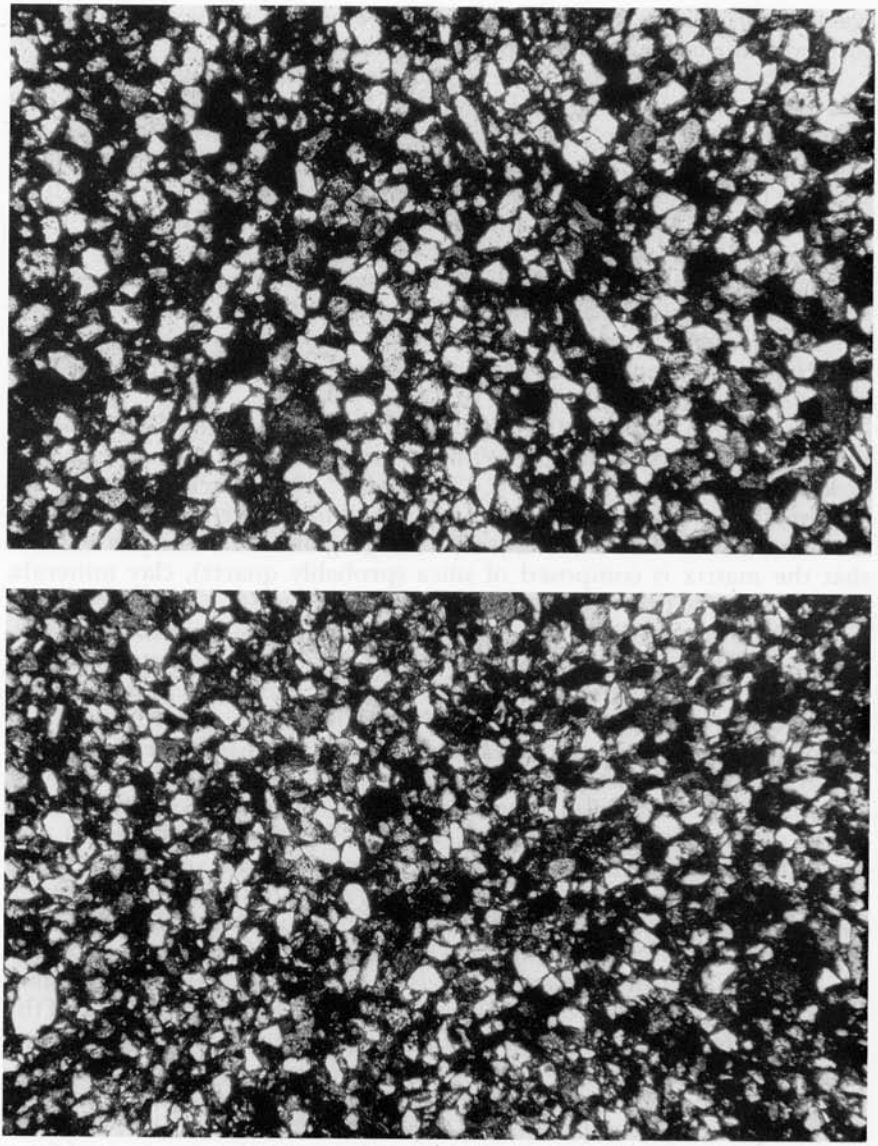

Fig. 4. Thin section photomicrographs (field of view equals 4.4 mm). (A) Sample 1914. Note subangular to subrounded quartz and K-feldspar grains set in dark ferruginous matrix. (B) Sample 1914-1.

mica grains, and (3) tiny (1 micrometer long) particles dispersed throughout the ferruginous matrix. Reconnaissance WDS analyses of both samples indicate that the clays have A1-Si stoichiometry appropriate for the kaolinite group. The aggregates of kaolinite-group minerals appear to be pseudomorphs (fig. 5). Their equant to elongate shapes suggest they formed at the expense of feldspars and micas.

Altered mica.—Altered mica fragments less than about 100 micrometers long are present in both samples. Because a few fragments still contain patches of high birefringence material pleochroic in shades of green and/or brown, the original mica was probably biotite. EDS analyses indicate that the alteration products are primarily chlorite, sericite (fine-grained K- and Al-rich clay), and kaolinite group minerals.

Altered plagioclase.—Both rocks contain small amounts of highly altered plagioclase grains about 50 micrometers or less in diameter. In spite of the significant alteration to fine-grained clays, primary lamellar twinning is still recognizable.

Hematite.—Hematite is present as about 1 to 10 micrometer long grains in the ferruginous matrix (fig. 5).

Ferruginous matrix.—The ferruginous matrix is red to dark brown in plane polarized light (fig. 4). With the nicols crossed, it transmits very little light and appears nearly "isotropic." The matrix minerals are extremely fine-grained and thus are difficult to resolve petrographically. Reconnaissance electron microscope imaging and EDS analysis indicate that the matrix is composed of silica (probably quartz), clay minerals, Fe-rich material (limonite), and traces of dolomite.

Calcite matrix.—Both samples contain irregularly shaped single crystals and crystal aggregates of calcite which occur as matrix cement between quartz and feldspar grains (fig. 5). The calcite contains tiny (about 1 micrometer diam) patches of hematite or limonite, which color it rusty brown in plane polarized light. The calcite consists predominantly of $CaCO_3$ but also contains traces of Fe and Mg (EDS analysis).

Lithic fragments.—Both samples contain equant to ovoid lithic fragments of ferruginous siltstone which range in length from about 1 to 3 mm. The fragments are composed of the same minerals and matrix as the host sandstones but are noticeably finer-grained (quartz grains are typically about 5–50 micrometers in diam). Modal abundances of lithic fragments for samples 1914 and 1914-1 are 3 and 1 percent, respectively.

Chemical comparison of detrital K-feldspars.—The chemical composition of alkali feldspar varies widely depending on the bulk composition of the magma or rock in which it forms and the pressure and temperature of crystallization. For example, the typical ranges in alkali feldspar composition for plutonic and volcanic rocks are about Or_{20} to Or_{97} and Or_{20} to Or_{75}, respectively (compare Deer, Howie, and Zussman, 1992; Or is the mole fraction of $KAlSi_3O_8$). As a result, different sandstones derived from different source terranes will, in general, contain feldspars with different compositions. Therefore, a critical test of the hypothesis that samples 1914 and 1914-1 represent the same rock unit is to determine if their alkali feldspars have the same chemical composition.

Testing for compositional differences requires statistical techniques that account for the closure problem and the multivariate nature of compositional data. Compositions only provide information about the

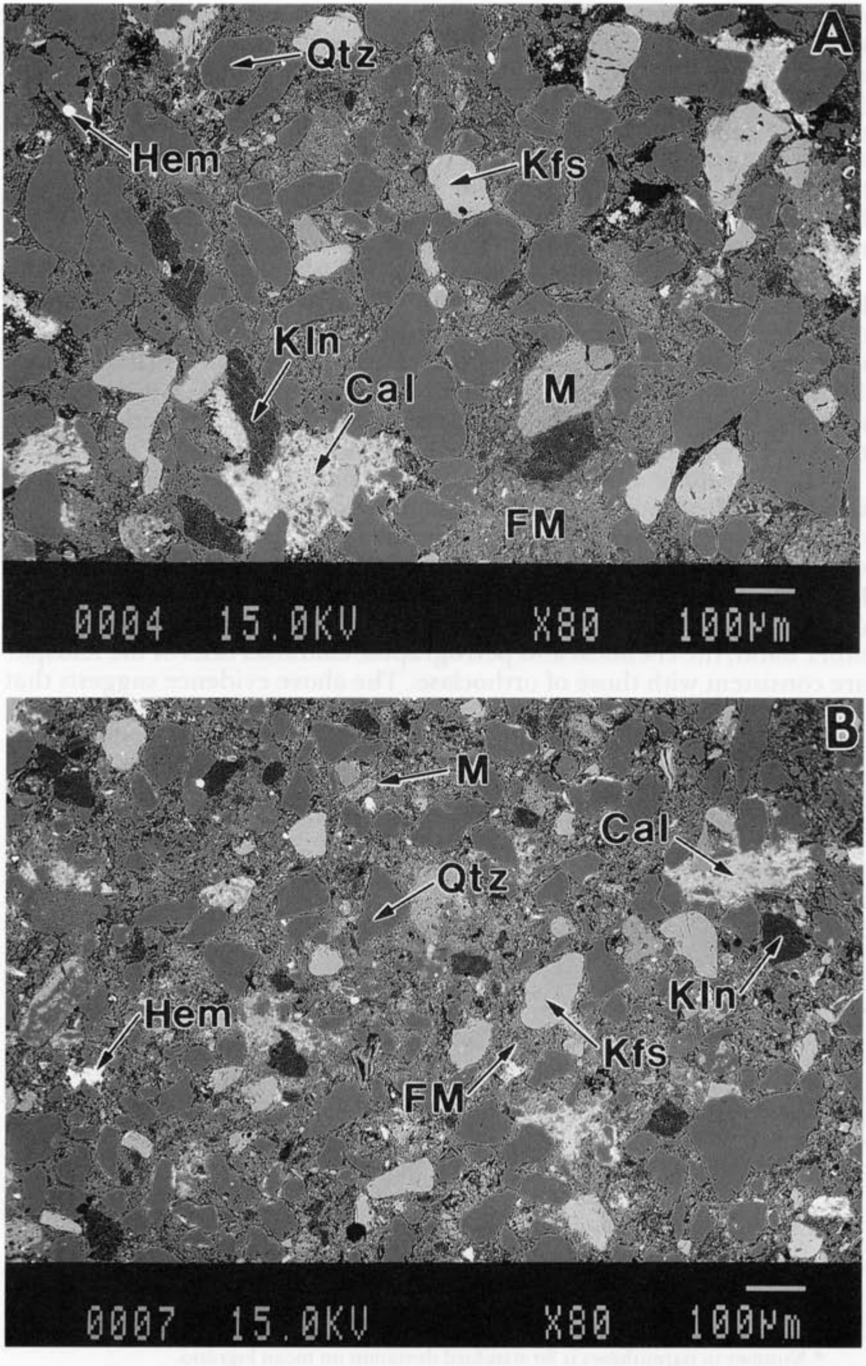

Fig. 5. Back scattered electron microscope images of the major detrital minerals and matrix materials. Qtz, quartz; Kfs, K-feldspar; Kln, kaolinite; M, altered mica; Hem, hematite; FM, ferruginous matrix; Cal, calcite matrix. (A) Sample 1914. (B) Sample 1914-1. Note overall similarity to sample 1914.

relative magnitudes of their components, and, therefore, statistical analysis should focus on component ratios (compare Aitchison, 1986; Woronow and Love, 1990; Ague, 1994). As justified in detail by Aitchison (1986) and Woronow and Love (1990), the statistical tests should be done on the means of the logarithms of the ratios, rather than on the raw mean ratios. For our purposes, Na/K is the primary ratio to investigate since the dominant alkali feldspar solid solution involves the $KAlSi_3O_8$ and $NaAlSi_3O_8$ endmembers. In addition, because the feldspars contain minor Ba, their Ba/K and Ba/Na systematics were compared.

The analytical results presented in table 2 demonstrate that the feldspars in samples 1914 and 1914-1 have very similar compositions (Or_{92-93}). Statistical comparisons using parametric *t*-tests (compare Woronow and Love, 1990) indicate that mean ln(Na/K), ln(Ba/K), and ln(Ba/Na) for feldspars in samples 1914 and 1914-1 are statistically indistinguishable. In other words, average feldspar compositions in the two samples are the same within the limits of resolution.

Petrographic observations and chemical analyses provide constraints on the type of alkali feldspar (for example microcline, sanidine, or orthoclase) in the rocks. The feldspars lack "tartan" twinning, so it is extremely unlikely that they are microcline. The K-rich nature of the feldspars is not consistent with sanidine, because most natural sanidines contain less than about 75 percent of the $KAlSi_3O_8$ endmember. On the other hand, the chemical and petrographic characteristics of the feldspar are consistent with those of orthoclase. The above evidence suggests that

TABLE 2
Feldspar analyses

	1914	1914-1
SiO_2	64.45	64.56
Al_2O_3	18.61	18.24
FeO	0.03	0.07
CaO	b.d.	b.d.
BaO	0.42	0.38
Na_2O	0.74	0.61
K_2O	15.52	15.61
Total	99.77	99.47
	Structural Formula (8 O)	
Si	2.99	3.00
Al	1.01	1.00
Ba	0.01	0.01
Na	0.07	0.06
K	0.92	0.93
$\log_e$(Na/K)*	−2.71 (0.38)	−2.97 (0.51)
$\log_e$(Ba/K)*	−5.63 (1.26)	−5.06 (0.48)
$\log_e$(Ba/Na)*	−2.92 (1.01)	−2.09 (0.40)

Note: b.d. = below detection.
* Number in parentheses is 2σ standard deviation on mean logratio.

the feldspar is orthoclase, but we note that to be certain of the feldspar's identity, X-ray work must be done.

The K-rich nature of the feldspars and the lack of intragranular deformation features in the quartz grains suggest that intrusive granitic rocks were an essential source component for the sandstones (compare Pettijohn, 1975; Deer, Howie, and Zussman, 1992).

Synthesis

The results of our comparative petrographic and mineral chemistry study can be summarized as follows. First, the samples appear identical to each other in hand specimen. Second, both samples are rather poorly sorted arkosic wackes characterized by subangular to subrounded quartz and alkali feldspar (Or_{92-93}) grains set in a fine-grained, limonite-bearing matrix. The same suite of detrital grains and matrix minerals is present in both samples. Third, sample 1914 contains somewhat more quartz (relative to the other grains and the matrix) and is slightly coarser-grained than 1914-1. Fourth, both samples contain small amounts of equant to ovoid ferruginous siltstone lithic fragments ranging in length from ~1 to 3 mm. Fifth, both samples contain ~12 modal percent cryptoperthitic K-feldspar. The average compositions of K-feldspar grains in both 1914 and 1914-1 are the same within the limits of resolution. Finally, intrusive granitic rocks were probably an important source component for both sandstones.

We conclude that samples 1914 and 1914-1 are virtually identical in terms of their petrographic characteristics and mineral chemistry and thus were probably collected from the same rock unit. Differences in grain size and modal quartz/matrix ratio suggest that 1914 was deposited in a slightly higher energy sedimentary environment than 1914-1. These differences in no way preclude our interpretation that 1914 and 1914-1 represent the same rock unit because small variations in grain size and modal abundance are common within individual sandstone beds (Pettijohn, 1975).

CONCLUSION OF THE *HALLOPUS* ENIGMA

On the basis of the analysis reported here, the original site of *Hallopus victor* can now be certified as located in W 1/2, NE 1/4, sec. 28, T.17S., R.70W., Fremont County, Colorado! The original stratigraphic provenance of *Hallopus victor* YPM 1914 is the upper part of the Morrison Formation of Late Jurassic (late Oxfordian to early Tithonian) age!

All contrary statements are incorrect. The statement by Norell and Storrs (1989, p. 19) that "red beds of the type composing *Hallopus* matrix are unknown from the Morrison at Garden Park or elsewhere" is now known to be incorrect.

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Appendix

Thickness of the Morrison Formation at Canon City, Colorado

Author	Thickness
Cope (1879)—notes	119 to 148 m (400-500 ft)
Cross (1894)	104 m (350 ft)
Hatcher (1901)	133.5 m (450 ft)
Mook (1916)	94.7 m (319 ft)
Osborn and Mook (1921)	95.0 m (320 ft)
Hassinger (1959)	105.7 m (346 ft)
Brady (1967)	109 m (357 ft)
This study	150 m (507 ft)

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