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Skeletal Study of the Hominins from Hotu and Belt Caves, Iran An Example of Conservation Gone Wrong

Jennifer McAuley
University of Pennsylvania

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Abstract

Most anthropologists agree that Neandertals disappeared ca. 40,000—30,000 years BP* (Larsen, 2008). Recent genomic research has indicated that Neandertals may have interbred with modern humans (Durand et al., 2011). In the 1950s at the University of Pennsylvania Museum of Archaeology and Anthropology, Mesolithic human (hereafter referred to as hominin) bones from Hotu and Belt Caves, Iran, were radiocarbon dated to approximately 8,000—11,000 years BP. However, these radiocarbon measurements were taken in the early 1950s before dating techniques had been refined and before the need for calibration curves had been realized. The scientist in charge of dating the samples remarked herself that the dates did not fit with the given context and that she feared contamination had ruined the results. Preliminary investigation of the remains indicates that at least one cranium, Belt Skull No. 2, presents both Homo sapiens (modern human) and Homo neanderthalensis (Neandertal) skeletal traits. I propose to examine the physical characteristics and determine the absolute age of the Mesolithic hominin skeletal remains from Hotu and Belt Caves, excavated by Dr. Carleton S. Coon of the Penn Museum in 1951-1952 in Northern Iran. These remains and their absolute age hold great implications for the relationship between modern humans and Neandertals, including the feasibility of interbreeding. In order to understand the relationship between hominin species, a reliable radiocarbon date must be made available for the Hotu and Belt Cave hominins. Dr. Janet Monge supervised the analysis and sampling of the skeletal material. Procuring a specimen fit for modern radiocarbon dating has proved difficult, as undocumented conservation techniques applied in the field and in the museum have contaminated a majority of the skeletal collection. Additionally, the radiocarbon dates from the 1950s must be calibrated in order to account for natural carbon isotope fluctuations and isotope fractionation.

Disciplines

Anthropology

Skeletal Study of the Hominins from Hotu and Belt Caves, Iran

An Example of Conservation Gone Wrong

By
Jennifer McAuley

In
Anthropology

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Dr. Janet Monge, Thesis Advisor

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Abstract

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Procuring a specimen fit for modern radiocarbon dating has proved difficult, as undocumented conservation techniques applied in the field and in the museum have contaminated a majority of the skeletal collection. Additionally, the radiocarbon dates from the 1950s must be calibrated in order to account for natural carbon isotope fluctuations and isotope fractionation.

**n.b. BP denotes years Before Present, Present is defined as 1950 CE (AD).*

Hypothesis

The skeletal remains are those of a Mesolithic population and are somewhere between 11,000 and 8,000 BP. Therefore, the original dating was somewhat correct, but imprecise and inaccurate due to possible contamination and the fact that radiocarbon analysis had not yet been refined. The remains are of an archaic *Homo sapiens* population; the Neandertaloid characteristics are idiosyncratic anomalies.

If this hypothesis is incorrect, and the Neandertaloid characteristics do exist and are signs of interbreeding between archaic human populations and Neandertals, then the broader context of Neandertal extinction and human interactions must be reexamined.

Introduction

Dr. Carleton S. Coon, infamous for his work entitled "The Origin of Races" and his other horrifyingly racist publications and personal views, was a Professor of Anthropology at the University of Pennsylvania. During the late 1940s and early 1950s, Coon led several archaeological expeditions in the Near East; these excavations, although real, have been rumored to be an elaborate ruse in order for US government intelligence operatives to gain access to volatile border regions, especially in Iran and Iraq, during the Cold War. Carleton Coon himself is rumored to have been employed as an intelligence operative by the US government.

Despite his checkered past, Coon kept excellent records and employed the most scientific excavation techniques of his day. Coon's digs were some of the first to be radiocarbon dated by Dr. Libby of Chicago, the pioneer of radiocarbon dating. Many faunal and ceramic experts were consulted in analyzing the finds from Coon's excavations.

Coon's reported motive for exploring far flung regions of the Near East was to better understand Paleolithic and Mesolithic populations of the area, their migration patterns, and how those populations influenced the origin of modern humans in the Near East and Europe. **Figure 1**, at right, shows Coon's proposed "Stone Age Migration Routes in the Middle East," focused on well-known archaeological sites and his own excavations (Coon

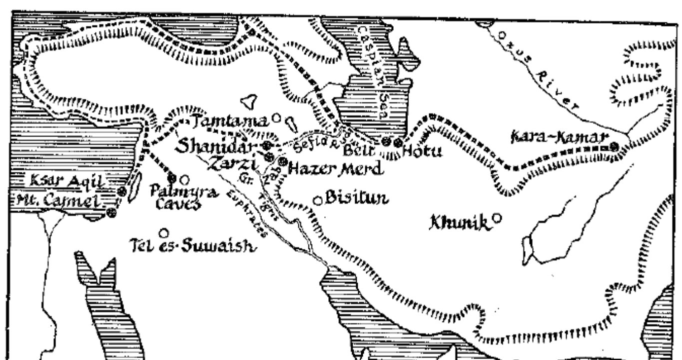


Figure 1

1951, 322).

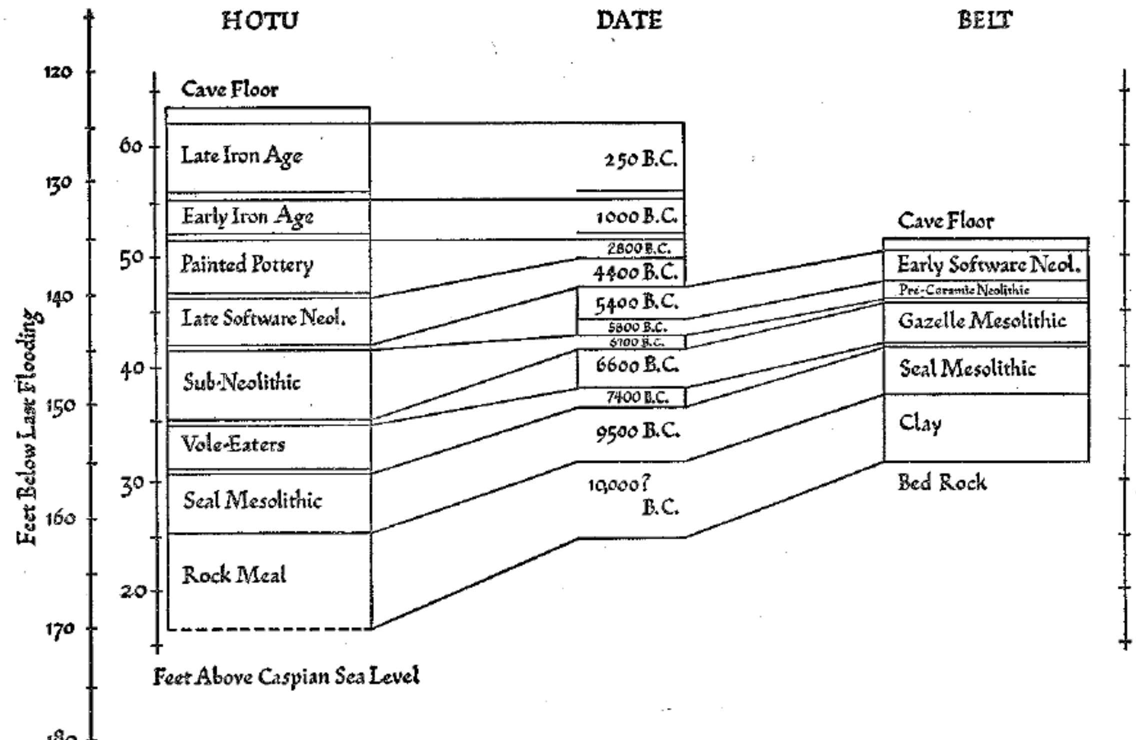
After the excavations, all of the material collected was shipped back to Philadelphia and remains in the Penn Museum collection to this day. The faunal, stone, ceramic, and hominin remains are all housed by different departments within the museum. The hominin remains are housed by the physical anthropology department, directed by Dr. Janet Monge. Of notable interest are the remains from Hotu and Belt Caves, Iran. These two sites, which are located closely together both temporally and spatially, can be treated as being occupied by one singular population. Coon himself was very interested in the hominin remains from these caves, and how their place in the chronology of the region would help to define the events of human evolution. Six fairly intact skeletons, three each from Belt and Hotu Caves, were excavated from the Mesolithic strata.

Although seven caves were excavated by Coon, I have chosen to focus this thesis on the excavations of Hotu and Belt Cave on the Caspian Shore. Much material was removed from these caves, ranging from modern artifacts to the Paleolithic. I will focus on the Mesolithic hominin remains from Hotu and Belt, as they are some of the most complete and academically interesting specimens from the Coon collection. Much further work exists and should be conducted on the other remains excavated by Coon in the Near East.

Background

Brief Geologic History of the Area

Hotu and Belt Caves are located in modern Iran on the southern shores of the Caspian Sea. These caves, found in Jurassic limestone, were cut by wave action sometime in the Pleistocene epoch (Ralph 1955, 149). As the level of the Caspian Sea fluctuated at the end of the Holocene with various glacial and interglacial events, the caves were repeatedly exposed, flooded, cut, and filled in. By the Paleolithic, the glaciers had retreated and the sea level was dropping, yet, continuing to fluctuate, and Hotu and Belt Caves were continually exposed. Due to their advantageous location, these caves were prime spots for shelter and settlement by early hominins. The fluctuation of sea level can be seen in the collected faunal remains: at Belt Cave, the Mesolithic layers alternate between marine and terrestrial faunal remains, seemingly in accordance with the fluctuating Caspian Sea levels (Coon 1957, 324). Overtime, various river and sea flooding events have deposited clay to gravel sized particles, created a sealed stratigraphy. Since Hotu and Belt Cave are located only a few kilometers apart from one another, their stratigraphies are highly correlatable and the hominins which inhabited them can be treated as one singular population. **Figure 2** below shows Coon's own correlation of the stratigraphy of Hotu and Belt Caves as well as the radiocarbon dates available at the time.



Belt and Hotu caves: correlation of Carbon-14 dates. **Figure 2**

History of Coon's Excavation in Belt and Hotu Caves, Iran

In the late 1940s through early 1950s, Dr. Carleton S. Coon of the University Museum (now the Penn Museum of the University of Pennsylvania) set out from Philadelphia to explore ancient caves in the Near East, searching for remnants of Paleolithic man. According to Coon, the great variability of caves, including the unequal dissolution of limestone, was what drew him to begin cave-digging (Coon 1957, 10-11). It was Coon's self-proclaimed goal to discover the "upper Paleolithic breeding ground" of hominins (Coon 1957, 128).

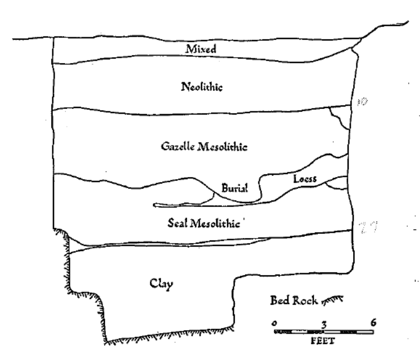
Allegedly a spy for the US government, Coon explored remote border regions of Iran. In the limestone outcrops surrounding the Caspian Sea, Coon found caves rich with Neolithic remains: Hotu, Belt, Bisitun, the High Cave of Tangier, Kara-Kamara, and two caves in the desert near Palmyra. However, he was looking for earlier remains from the Paleolithic and Mesolithic in order to better understand modern human origins. Notably, the caves of Hotu and Belt have yielded significant Mesolithic hominin remains. Coon postulated that Paleolithic hominin remains could be found if additional caves were found and excavated above the Caspian Sea glacial high water mark, as Hotu and Belt were only exposed to hominins at the very end of the Paleolithic or very earliest Mesolithic times (Coon 1957, 324).

Coon employed local workers to excavate his sites. He laid out rectangular trenches, and had his work men remove debris in 20 cm increments, each increment he dubbed a "Level." At both Hotu and Belt Caves, Neolithic artifacts were present in the top horizons. Unfortunately, Coon's excavations were plagued by conflict between the workers; men from different villages and differing ethnic groups were constantly squabbling. As the result of such squabbling, several hominin remains were destroyed (Coon 1959, 157). Additionally, tension from the Cold War and ongoing political strife made its way into the excavations, pitting the local workmen against the American and European directors.

Belt Cave

Carleton Coon began excavations at Belt Cave (locally known as Ghar-i-Kamarband) in early 1949. After ejecting a family of dervishes, Coon began clearing the cave with the help of five local workmen. The floor of the cave was 4.5 meters above a stream bed that passed in front of the cave and approximately 16 meters above sea level (Coon 1951, 142—143). Coon constructed Trench A in order to better understand the stratigraphy. Many Neolithic remains were discovered in the top ten Levels of Belt Cave. In Levels 11—17, Coon discovered extensive evidence of Mesolithic hominins, including hominin remains, flints, and an abundance of charred animal bones including red deer and Caspian seals (Coon 1951, 156, 158). Level 25 marked sterile, varved clay (indicated seasonal lake deposits) and the end of cultural horizons in the cave. Bedrock was reached at a total depth of 5.60 meters (Coon 1951, 161).

Trench B, an extension of Trench A, was excavated during the final two days of the excavation in 1949. Only Neolithic remains were discovered. **Figure 3** at right shows a generalized section of Belt Cave (Coon 1959, 146).



Belt Cave: section.

Figure 3

In Belt Cave, a burial (Belt Cave, Skull No.2) was discovered in Trench A spanning Levels 19—21, which Coon attributed to the lowest level of the Upper Mesolithic cultural horizon (Coon 1951, 79). The remains of three individuals (an young adult male, a middle aged male, and a pre-pubescent 12-13 year old female), which were coated with red ochre, were within a pocket of intrusive soil, indicating that the bones had been purposefully painted and ritually buried after death (Coon 1951, 79). Unfortunately, upon discovering the first skeleton, one of the workmen smashed the skull with a pickaxe out of fear (Coon 1951, 157). The skull was reconstructed with wire and vinolite by Dr. J. Lawrence Angel. Upon closer inspection, Coon and Angel determined that the remains were that of a young adolescent girl, aged 12 or 13 years at her time of death (Coon 1951, 79). These remains are most peculiar, described by Coon as belonging to *Homo sapiens* but yet also possessing clear Neandertaloid traids, including a "deep lower occiput, flat temporal squama, sloping forehead, tilted masticatory region with short madibular ramus compare to the face size, prognathism, a weak chin,… [and] big teeth" (Coon 1951, 80). Coon himself remarks that her archaic skeletal features cause her to "deviate(s) in a Neanderthaloid direction" from modern human skeletal features (Coon 1951, 80).

Two years later, Coon returned to Belt Cave in February of 1951 in order to continue his excavations and gather charcoal samples that could be radiocarbon dated, a revolutionary technique that had only just emerged. Notably, a Neolithic male skeleton and a female with an infant in her arms were discovered within the first few days of the excavations (Coon 1951, 166—167). The excavators discovered that the Seal Mesolithic layer was indeed the oldest habitation level, as they hit bedrock again below.

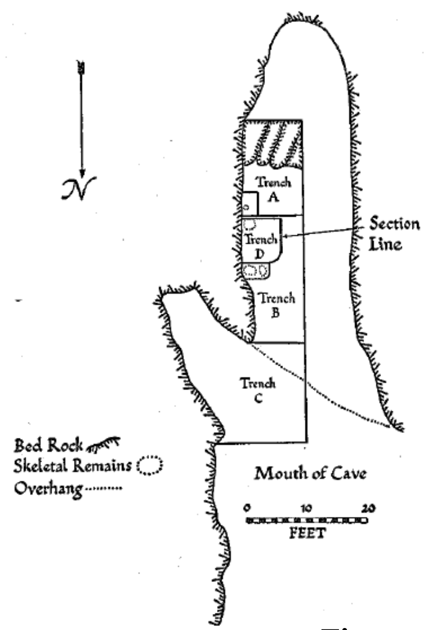
Levels 15-16, which lay approximately 40 cm above Level 19, were dated to 8545 ± 510 BP by Dr. Libby (Libby and Arnold 1951, 112). Levels 26, 27, and 28, approximately one meter below Mesolithic juvenile female skull were dated to 8004 ± 1010 BP. According to the laws of superposition, the skeletal remains should be younger than Levels 26-28 and older than Levels 15-16. However, the ages of the radiocarbon dated levels seems reversed. These dates were obtained by dating charred animal bones in the levels. Several years later, Dr. Elizabeth Ralph of the University of Pennsylvania also assigned radiocarbon dates to the levels in Belt Cave. Ralph's dates seemed more reliable, as she calculated over 20 dates, yet the absolute chronology still remained problematic.

In order to get an accurate date for hominin remains from the caves, the remains themselves must be radiocarbon dated. Too many unknowns exist when attempting to date charred animal bone or charcoal: contamination, groundwater action, etc. Furthermore, the primitive features must be measured and compared to other populations in order to determine if Neandertal traits are present and what the implications are for human and Neandertal admixture.

While excavating at Belt Cave, Coon's workmen alerted him to another nearby, similar cave: Otu or Hotu.

Hotu Cave

Much larger than Belt Cave, Hotu had been discovered by accident during a blasting operation to mine the local limestone. The floor of the cave was well above sea level and approximately 15 meters long and 4.5 meters wide (Coon 1951, 163). Initial discovery of the cave occurred on February 1951, while Belt Cave was also being excavated. Official excavation of Hotu began in the afternoon of March 14, 1951 (Coon 1951, 174). During the first few days of the excavation, several meters of Iron Age and Neolithic deposits were removed and were found to be rich in both metal and stone tools and ceramics. Many butchered and charred animal bones were found within these young layers (Coon 1951, 176—179). **Figure 4** at right shows Coon's sketch of the trenches laid out in Hotu Cave (Coon 1957, 175). Although the excavations at Hotu only lasted a little under two months while the excavations at Belt spanned two full seasons, in that short time at Hotu, great and unique discoveries were made.

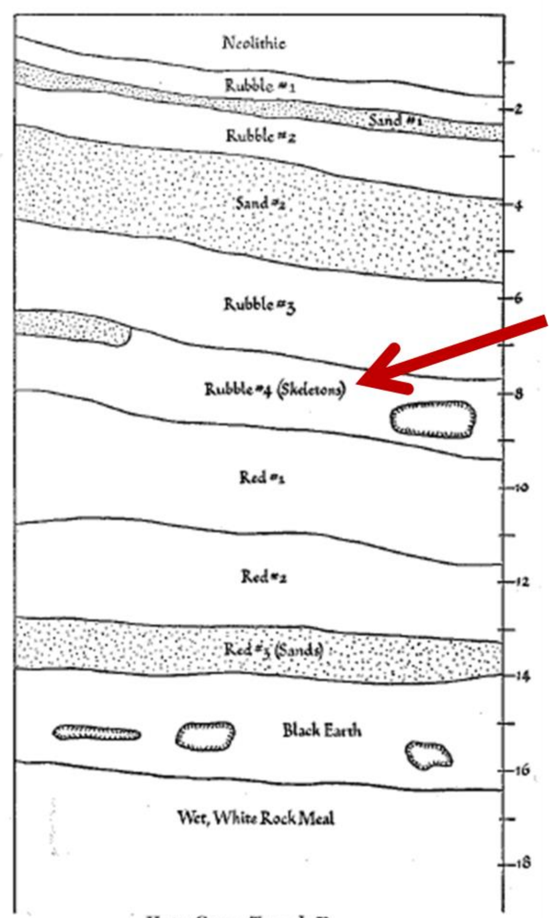


Hotu Cave: plan. **Figure 4**

The importance of the elevation of Hotu cave is paramount to the age of the hominin fossils found within. Given the fluctuations of the Caspian Sea, Belt cave was only above sea level during the Mesolithic but Hotu Cave, which is considerably higher above the modern sea level, was exposed not only during the Mesolithic but also during the late Paleolithic. Thus, hominin fossils of Paleolithic date were found in the cave while completely lacking in nearby Belt Cave.

The first skeleton was discovered on March 16th, 1951 at three o'clock in the afternoon, local time (Coon 1957, 199—200). Located within a later of rubble (Rubble #4 from Coon's field notes), the remains were disarticulated, suggesting that sometime after death and decomposition, the remains had been gathered up and placed in a corner of Hotu Cave and were then subsequently covered as sediment naturally filtered into the cave. The bones seemed to be neatly stacked, suggesting that they have been purposefully moved by another hominin rather than strewn about by local fauna or water action. Although much of the skull of the first skeleton was missing, the femurs, mandible, and several long bones were fairly intact. This skeleton was given the name "Hotu Skeleton #1" and eventually catalogued under the number 52-86-44 (Angel 1951, 265).

Digging continued and on March 17th and 18th, 1951, two more skeletons were unearthed: Hotu Skeleton #2 and Hotu Skeleton #3. These remains were found approximately 75 centimeters below Skeleton #1 still within rubble layer four (Coon 1959, 202). The skeletons were lying overtop a small hearth of charcoal and seemed to have been killed and buried by a large slab of rock falling from the cave ceiling (Coon 1957, 207). These three skeletons were assigned and age of 9,335 ± 350 BP by Coon after receiving and "averaging" the radiocarbon date of the charcoal hearth from Rubble #4; Ralph dated this level to 9190 ± 590 BP while Krups dated this level to 9480 ± 250 BP (Coon 1957, 207; Ralph 1955, 150—151). At the time, these were some of the older remains to be found in Iran. The hominin skeletons were and are invaluable to understanding the broader context of early migrations of Mesolithic populations. **Figure 5**, at right, shows the gravel layer ("Rubble # 4) in which all three skeletons were found at Hotu (Coon 1957, 200).



Hotu Cave: Trench D, **Figure 5**

Notably, several Paleolithic style tools were found within and atop of the Mesolithic rubble layers (Coon 1959, 206). This initially confused the excavators, as several thousands of years and several meters of sediment should separate the two tool technologies, yet the Paleolithic and Mesolithic appeared in Hotu Cave comingled. Coon hypothesized that perhaps Mesolithic peoples had found the older Paleolithic tools lying about the caves or the surrounding region, picked them up, found them useful, and continued to use them while also fashioning their own unique tools (Coon 1959, 206). Another interesting possibility could be that the inhabitants of Hotu Cave had contact with, or were the result of interbreeding with, a different hominin population that utilized a different tool technology. Could lingering Neandertals have been responsible for the Paleolithic tool assemblages found in the Mesolithic layers and for the slightly odd skeletal anomalies present in some of the skeletal remains, especially at Belt Cave? No conclusion can be made on this matter; extensive analysis of the lithics from both Hotu and Belt must be undertaken to elucidate the problem of the asynchronous yet coterminous stone tools.

Plagued by unrest amongst the workmen, problems with funding, unstable walls, lack of oxygen within the 10+ meter deep trenches, and constant threat of rockfalls, the excavation at Hotu sputtered into late April of 1951. After one disastrous cave in, On April 20th, 1951, Coon and his colleagues packed up their tools and finds and departed the archaeological site, never to return (Coon 1959, 205—206).

Coon's Comments on the "Men in our Caves"

In 1957, Coon wrote a brief descript of "the men" found while excavating several caves in the Near East, including Hotu and Belt Caves. During his time in the Near East, Coon excavated a total of seven caves. Four of these caves contain hominin skeletons: the High Cave at Tangier, Bisitun, Belt, and Hotu (Coon 1957, 326). There, Coon excavated fifteen individual prehistoric skeletons, seven of which were fairly complete (Coon 1957, 317). All of these skeletons dated from the Upper Paleolithic to the Neolithic. Coon calls the remains from Bisitun as being Neandertal like, while those at Hotu more "European" and goes on to make several sweeping, unfounded generalizations about the ancestries of the skeletal remains (Coon 1957, 327).

Belt Cave yielded three relatively intact skeletons, the first Mesolithic peoples to ever be found in Iran, at least according to Coon (Coon 1957, 324). However, the hominins from Belt Cave, especially Belt Cave Skull No. 2, present odd features, Coon notes that they seem to share both Neandertal and "European" [read: modern *Homo sapien*] characteristics (Coon 1951, 79). Some of the remains, especially those of three comingled individuals from Levels 19-21 at Belt had been painted with red ochre (Coon 1951, 79). Coon notes that the stratigraphies of the Mesolithic Hotu and Belt Cave deposits are very similar to those at Shanidar in Iraq, where the famous Neandertal skeletons have been excavated. These findings from Belt Cave troubled Coon, and pressed him to postulate that the line between Neandertal and human had blurred in the Near East (Coon 1957, 335).

Hotu Cave yielded five individual hominins, the skeletons of which three (Skeletons #1, #2, and #3) were relatively intact. Skeletons #4 and #5 were represented by single bone fragments.

Given the intriguing and somewhat perplexing hominin remains found at Hotu and Belt, it is clear that further excavation, if undertaken, could yield enormously powerful contributions to the corpus of Near Eastern prehistoric hominin populations.

Skeletal Analysis by Dr. J. Lawrence Angel

Dr. John Lawrence Angel, a biological anthropologist and former student of Coon's, examined the skeletal material from Hotu Caves in 1951. At that time, he held a position as Associate Professor of Anatomy and Physical Anthropology at Jefferson Medical College in Philadelphia, PA. Angel completed preliminary reconstructions of the specimens using vinolite, a type of plastic material popular during the first half of the twentieth century (Coon 1951, 57). The reconstructions have not aged well, having become quite discolored and rather brittle. Angel's findings were published in the Proceedings of the American Philosophical Society, volume 96, number 3 in June of 1952. The finds from Belt Cave were not studied by Angel; however, they were briefly described by Coon in his 1951 publication, *Cave Explorations in Iran.*

Coon had excavated three fairly complete Mesolithic skeletons (Hotu Skeletons #1, #2, and #3) from Rubble #4 as well as skeletal fragments from two other individuals in Hotu Cave in 1951. The remains of these five hominins were the focus of Angel's work. Angel noted that the bones were fairly well preserved for their apparent age, a result of the continuously damp conditions within the sediments of Hotu Cave (Angel 1952, 259). Angel also choose to treat all of the hominin remains from Hotu as one singular population, although they are separated by nearly a meter of sediment, all remains were found in the same gravel layer and suggest at least a relatively close temporal relationship, on the scale of one to a few generations removed (Angel 1952, 259).

As previously described, Skeleton #1, a male, was found approximately 75 centimeters above Skeletons #2 and #3. Skeleton #1 had been moved after death and decomposition; seemingly, another hominin stacked and organized his bones in the back of Hotu Cave. The skull of Skeleton #1 was found nearly a meter removed from the postcranial remains, suggesting that after the bones were stacked and organized, they were disturbed, possibly by local fauna or water action. The skull is extremely smashed, but the maxilla and mandible are fairly complete. Angel puts Skeleton #1 at 175.7 centimeters (5'9") and between the ages of 30-40 years at time of death (Angel 1952, 260). What remains of Skeleton #1's skull is quite robust, with a square jaw, prominent chin, and a mandible with teeth more widely set than the maxilla (Angel 1952, 260).

Skeletons #2 and #3 were comingled and found huddled above a charcoal hearth, seemingly killed by an unexpected rockfall from the cave roof. Angel postulated that Skeletons #2 and #3 may have tumbled backwards and fallen at the time of their death, given the fact that their heads were found at lower elevations than their lower extremities (Angel 1942, 258).

Skeleton #2 was described as a 167.4 cm (5'6") individual slenderly built, but with robust muscle attachments, suggesting a well-muscled frame (Angel 1952, 259). The skull robusticity suggested that Skeleton #2 was male, yet the pelvic features were on the borderline of male and female characteristics. However, the large sciatic notch and apparent roughening of ligament attachments in the pelvis suggest that the individual was indeed female and suffered stress from carrying children (Angle 1952, 259). Given the maturity of the skeletal remains and the dentition, Angel assigned an age at death of 27 years. Angel calls the skull of Skeleton #2 Cro-Magnon like, given its square jaw and protruding chin (Angel 1952, 260). Skeleton #2's femurs are notably bowed and the femoral necks are tilted at 29 degrees (Angel 1952, 259—260).

Skeleton #3, found *in situ* with Skeleton #2, is also the remains of a Mesolithic adult female. These remains indicated that Skeleton #3 was considerably shorter and stockier than Skeleton #2, standing at an estimated 156.9 centimeters (5'2") and extremely thick and bowed femurs and forearms (Angel 1952, 260). Angel notes that this individual appears to be in her mid to late 30's [37] and shows signs of arthritis in many of her joints, including the pelvic joints, hands, and lumbar vertebrae. Angel had an X-ray taken of both Skeleton #2's Skeleton #3's hands, **Figure 6** at right, clearly showing pathologic/arthritic damage. Comparatively, Skeleton #3's bone cortex is thinner and the trabecular bone is less dense than that of Skeleton #2; this can be viewed as a sign of comparatively advanced age (Angel 1952, 260 Fig. 8).

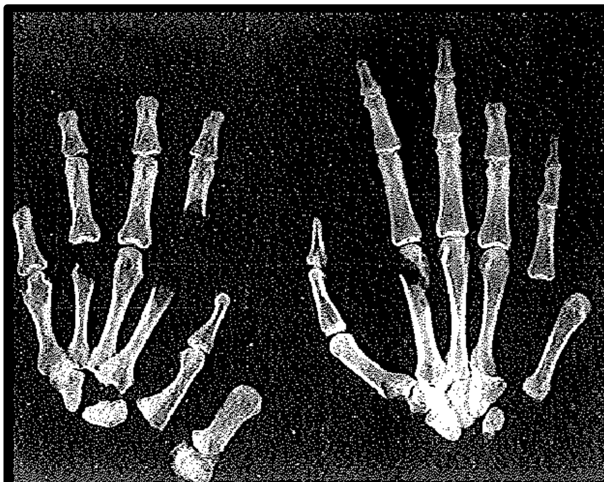


FIG. 8. Radiographs of hands. Hotu No. 3 (*left*) with right thumb added; Hotu No. 2 (*right*) with left fifth metacarpal substituted. Note pathologic changes in No. 3 at head of fifth metacarpal and first metacarpal-greater multangular joint.

Figure 6

The remains of Skeleton #4, which only consists of a left maxillary fragment, suggests that the individual may have been an adolescent female in her mid to late teens at time of death (Angel 1952, 260). The remains of Skeleton #5, even more fragmentary than Skeleton #4, consists of a single cranial vault segment, that Angle asserts may be similar to Skeleton #3 (Angel 1952, 260).

These five skeletal remains from the Mesolithic Hotu layers are fairly similar in morphology, and support Angel's decision to treat the specimens as one population. Angel asserts that the idiosyncratic differences in skeletal morphology are more likely due to small genetic factors than environmental (Angel 1952, 261), as all five skeletons were living in the Mesolithic age on the southern shores of the Caspian Sea. If the time, funding, and condition of the skeletal remains allowed, it would be worthwhile to pursue genetic sequencing of the five remains in order to test for familial relationships.

General Note on Mesolithic populations

Mesolithic human populations were hunter gathers learning how to deal with a post-glacial changing climate. The Neolithic revolution would come after their time and bring with it agriculture and domesticates. Characterized by their flint and other stone tool assemblages, Mesolithic populations are distinct from older Paleolithic populations in that their tools are more refined. Many flints have been collected from Coon's cave explorations, but will not be discussed here, as they are the work for an entire research project in its own right. In the caves that Coon was excavating, the Mesolithic bones often were not fossilized while the Paleolithic remains shows signs of permineralization.

General Note on Neandertals

Known to the academic world since 1864, Neandertals are undoubtedly the most famous and best studied of the fossil hominins (Klein, 1999). However, much remains unknown about *Homo neanderthalensis.* It is now generally accepted that Neandertals were not a direct ancestor of modern humans, but rather a closely related sister group with which admixture may have occurred (Klein, 1999). In general, most anthropologists agree that Neandertals appeared ca. 400-300,000 years BP (Larsen, 2008). However, some experts, such as Hublin (2009), push this date back to 600,000 years BP.

In Europe, the Neandertal-human distinction is very clear, however; in the Near East, published skeletal reports have been slightly less clear with some authors asserting the existence of one, highly variable late Pleistoncene *Homo* population, which includes both "humans" and "Neandertals" (Holliday, 2000). However, according to Holliday (2000), there is a clear distinction between "African-like tropically adapted" (modern human) and "European-like cold adapted" (Neandertal) skeletal morphologies; any haziness in the literature resulted either from poor archaeological work or skeletal material that was too fragmentary to properly analyze.

Many Neandertal remains have been excavated from the Near East. Shanidar Cave, Iraq, is one such location (Klein, 2002). There, the bones fit the generally accepted Neandertal timeline. Even though the Neandertals existed contemporaneously with modern humans in the Near East, next to nothing is known about Neandertal-Human interactions. The skeletal remains from Hotu and Belt Caves can help fill in the gaps in the Neandertal-human story. Fossil evidence clearly shows that the Neandertals disappeared by 30,000 years ago (Larsen, 2008).

Recent genomic evidence suggests that there was some interbreeding between Neandertals and fully modern humans (Durand et al., 2011). If the remains from Dr. Carleton Coon's excavations prove to be as young as he suggested and exhibit true Neandertal features, then there may be evidence for persistence of Neandertal-like hominids well beyond the generally accepted date.

When studying hominin, especially human, remains, ethical concerns must be considered. According to Soren Blau (2009), research on human remains should only occur if there is a distinct end goal that adds to the understanding of humanity. For this project, much knowledge about the shared human past stood to be gained by studying the hominin remains and outweighed the potential negative consequences of analyzing and sampling hominin remains. Furthermore, Blau notes that there is often a socio-economic bias present in modern human reference collections; this is a fact that must be addressed while completing research. Additionally, the great variability and lifestyle and diet and those effects on skeletal morphology must be considered (El Zaatari et al, 2011).

Early Radiocarbon Dating of the Samples

Dr. W.F. Livy of the University of Chicago was the first to pioneer radiocarbon dating. Dr. Coon sent four charred bone samples from Belt Cave and Libby was able to date three of these samples (Libby and Arnold 1951, 112; Libby 1951, 291). The first sample came from charred animal bone found in Levels 6, 7, 8, 9, and 10. This early Neolithic sample was dated to 8085 ± 1500 years before present (BP) (Coon 1949, 31). Mesolithic Level 11 was dated to 10,560 ± 610 BP. Another Mesolithic sample from Levels 15 and 16 was found to be 8545 ± 510 BP. The final sample from Levels 26, 27, and 28 was dated to 8004 ± 1010 BP (Libby and Arnold 1951, 112). Strangely enough, the stratigraphy of the Mesolithic layers seems to be inverted, with the younger radiocarbon samples located beneath the older samples. Given the law of superposition and the undisturbed nature of the deposits, this dating is troublesome and opens up doubts as to the accuracy of the dates. Coon himself admits qualms on the radiocarbon ages, remarking that "Something is obviously wrong, somewhere," (Coon 1951, 32).

Coon notes that the time intervals between strata seem enormously out of proportion—the interval between the late Mesolithic and the early Neolithic is way too large at 2,460 years, and even if the samples from Level 11 are thrown out, the time interval becomes too brief, allowing only 460 years for the passage of the mid-Mesolithic to the early Neolithic (Coon 1951, 31). Coon seems to pick and choose the date he wants his samples to be, remarking that he has a tendency to believe the date for the early Neolithic and reject the rest. In the late 1940s, radiocarbon dating was in its infancy. Today, much more precise methods, such as accelerator mass spectrometry, have evolved. Furthermore, the remains were buried in a limestone (calcium carbonate) cave. It is possible that as water ran through the cave, it dissolved carbon atoms with a much older date and percolated through the sediments, contaminating the charred animal bone samples and artificially ageing the top-most layers. This contamination would affect the dating of the apatite mineral of the bone. Theoretically, the organic carbon encased within the bone collagen could be uncontaminated.

Troubled by the inconsistency of the radiocarbon dates that Dr. Libby provided, Coon sent charcoal samples from the second field season from Belt Cave to Dr. Elizabeth Ralph of the University of Pennsylvania to be radiocarbon dated in her lab. Dr. Ralph dated two Mesolithic layers to 11,480 ± 550 BP (the Mesolithic cap layer) and 8,570 ± 350 BP (the "gazelle" Mesolithic) (Ralph 1955, 150—151). The intervening yellow soil layer was dated to 12,275 ± 825 BP.

Dr. Ralph went on to date samples from Hotu cave as well, which were also published in *Science*. Charcoal from a hearth directly underneath Hotu skulls 2 and 3 were dated to 9100 ± 590 BP which her colleague Dr. J. L. Kulp at Columbia dated to 9480 ± 250 BP (Ralph 1955, 150—151). Coon chose to "average" these ages together, citing the age of Skeletons 1, 2, and 3 as 9,335 ± 350 BP (Coon 1957, 207).

Again, after radiocarbon analysis, Coon considers some of the dates impossible, so he simply disregards them rather than trying to explain and understand the anomaly (Coon 1957, 207). Given the inconsistency of the early radiocarbon dates and the great advances made in the field, it is worthwhile to pursue reanalyzing and dating the bones directly, this time specifically targeting the bone collagen with accelerator mass spectrometry techniques.

Radiocarbon Dating and its Impact on our Understanding of Human Evolution

Prior to radiocarbon dating and other absolute dating methods, geologists and archaeologists could only assign relative dates to material based on Steno's laws and stratigraphic correlation. With the advent of the nuclear age and new technologies, it became possible to assign discrete, numeric ages to strata and specimens.

Since radiocarbon is most reliable when used to date objects between 300 and 45,000 years old, radiocarbon dating is not a useful tool for analyzing the earliest hominin ancestors. However, it is very useful in late Neandertal and early modern human contexts. Researchers employed both radiocarbon and U-series dating at the site of Abric Agut in Spain (Vaquero, et al. 2002). Vaquero used C^{14} to date a Neandertal tooth and establish a chronology for the site (Vaquero et al. 2002).

Radiocarbon dating can be used to date new world sites and help to establish when and how humans migrated to North America and the Pacific Islands.

However, there are complications that must be considered. Often, archaeologists and researchers attempt to date shell or bone artifacts. When dating shell artifacts, researchers must always be wary of the marine reservoir effect, isotopic fractionation, and the potential contamination caused by post depositional carbonates. However, with modern AMS techniques, it is very easy to take samples from the interior of the shell that have not been contaminated and apply the appropriate correction values for marine reservoir and fractionation effects.

When it comes to bones, it is possible to radiocarbon date both the organic collagen and the inorganic hydroxyapatite mineral. Experts prefer to date collagen whenever possible because it is less prone to contamination than hydroxyapatite as it is locked within the bone matrix; however, collagen decays rapidly over time and can still be contaminated. Hydroxyapatite is much more resilient and can be preserved for millennia. Yet, contact with soil and groundwater easily facilitates ion exchange and can quickly contaminate the mineral component of the bone with younger (or older, if the ground water is percolating through an ancient limestone bed) carbon isotopes, especially from carbonate rich ground water (Walker 2005, 31). Radiocarbon dating can yield excellent results, as long as all possible sources of contamination are accounted for.

Radiocarbon dating is also very applicable to charcoal finds at archaeological sites. The presence of charcoal indicates fire and can elucidate fire use and pyrotechnology. Since charcoal is almost pure carbon, very small quantities are needed for AMS analysis. However, contamination must always be considered, especially bioturbation and the leaching of organic acids through soil horizons. It is also possible to radiocarbon date peat and organic rich lake muds (Walker 2005, 42).

Dating of organic muds has been very useful in defining the chronology of Mesopotamia. Hritz et al. (2012) used organic rich marsh sediments in order to better define the chronology of the world's first cities. In archaeology, the establishment of agriculture and domestication of animals was a monumental step in human evolution and is used to define fully modern humans. Hritz et al.'s research also employed radiocarbon dating of shell and charcoal samples. The shells were of palustrine (inland, non-tidal) invertebrates, so the marine reservoir effects did not need to be corrected for (Hritz et al. 2012, 75).

Radiocarbon dating has been especially applicable to dating Paleoindian sites in North and South America. Direct dating of skeletal material and associated organic rich artifacts has allowed researches to construct a timeline for the migration of modern humans into the New World. Specifically, at Monte Verde, a site in Chile with excellent organic preservation due to a high ground water table, has yielded a radiocarbon date of approximately 14,800 years BP, pushing back the peopling of the Americas to sometime between 30-15,000 years BP (Dickinson 2011).

Other Current Research: Work being done by Drs. Michael Gregg, Ron Pinhasi, Daniel Bradley and Tom Higham

Dr. Michael Gregg, McMaster University, has actively been studying ceramic sherds and other non-hominin artifacts collected from Hotu and Belt Caves. He has been collaborating with Drs. Pinhasi, Bradley and Higham from University College Cork, Trinity College Dublin, and Oxford, respectively. These researchers are attempting to analyze worldwide Paleolithic populations in order to understand the complexities of human evolution since the Pliocene. By analyzing genetic (DNA, mtDNA, Y-chromosome DNA) and isotopic signatures (C^{13}/C^{12}, N^{15}/N^{14}, etc) and also by completing three dimensional digital scans of skeletal remains, the researchers hope to elucidate how and when the switch from hunting and gathering to farming took place. The researchers also radiocarbon date the bone samples at the C^{14} AMS Radiocarbon Accelerator facility at the University of Oxford. By analyzing many different skeletal collections representative of many different ancient populations, the researchers also hope to reconstruct past migration routes.

Several bone samples from the Hotu and Belt collection were loaned to these researchers for both radiocarbon and isotopic analysis. At the time that this thesis was written, no data, nor the leftover samples, had been received from these researchers.

Methods

Scientific Approach

Historically, many archaeological investigations have lacked scientific rigor. However, modern archaeology projects incorporate scientific techniques and replicable analytical methods (Miller 2009). For this project, I endeavored to incorporate as much rigor and scientific methodology as possible. Using White and Balck's *Human Osteology* (2012) Buikstra and Ubelaker's *Standards for Data Collection and Human Skeletal Remains* (1994) as guides, I and catalogued the bones, and attempted to rearticulate at many fragments as possible. Erik Trinkaus (2011) has recently published on the late Pleistocene hominin mortality patterns; his work provides critical reference data.

With the invaluable aide of Paul Mitchell, I recorded the bone measurements, conforming to Buikstra and Ubelaker's 78 diagnostic measurements. According to Sauer and Wankmiller (2009), variation in facial morphology can be used to identify different ancestral groups. The measurements were completed twice on two different occasions and then averaged in order to increase accuracy.

Dr. Monge and I selected one sample to be analyzed by C^{14} AMS dating. The sample was be shipped to Beta Analytic, a fully accredited radiocarbon dating lab that is in accordance with ISO-17025 standards. The sample was analyzed by a C^{14} AMS Radiocarbon Accelerator. The results were calibrated to account for isotopic fractionation and variable atmospheric C^{14} levels using delta C^{13} and the INTCAL 09 calibration curve. The dates generated by Beta Analytic were then compared to the dates produced by Libby and Ralph in the early 1950s.

The Question of a Reliable Radiocarbon Date: Recalibrating 1950s Data

The first question was: is it possible to recalibrate the radiocarbon dates produced by Libby and Ralph in the early 1950s? In a word, yes. However, the validity of those recalibrated dates is plagued by uncertainty and sources of error. The first tree-ring dendrochronology calibration curves were proposed in the early 1960s, well after Libby and Ralph dated their samples. It would seem reasonable that a calibration curve could be applied to the Libby and Ralph data because these data Libby and Ralph reported were raw radiocarbon ages rather than calibrated calendar ages. Although online calibration programs exist, the data generated by Libby and Ralph is not suited for calibration. First of all, the uncertainty associated with Libby and Ralph's result is roughly ten percent of the measured age. Libby and Ralph reported uncertainties ranging from ± 260 through ± 1,500 years. Modern uncertainty ranges are typically an entire order of magnitude less than these 1950s results; a reliable date with a 2-sigma confidence should only have an uncertainty on the scale of ± 50 years. Additionally, contamination of the original samples is almost certain (please see earlier discussion). Yes, it would be possible to recalibrate dates and even get reasonable age, but there would be no way to validate the results or have any confidence in the ages generated.

For the sake of argument, I have calibrated both Libby's and Ralph's 1950s radiocarbon dates with the INTCAL09 calibration curve, a widely accept and employed calibration curve. As can be seen in the plot below, the uncertainties are huge, and subsume the entire time period being looked at. At the time Libby measured the radiocarbon dates for Hotu/Belt, calibration of the radiocarbon age had not yet been discovered, so his data is a raw radiocarbon age, not a calibrated calendar age.

The first chart below shows Libby's, Ralph's and the AMS raw radiocarbon age for the Mesolithic samples from Hotu and Belt Caves. The second chart (next page) shows Libby's, Ralph's, and the AMS calibrated calendar dates for the Mesolithic samples from Hotu and Belt Caves. These two plots show radiocarbon age [**Chart 1**] and calendar age (years BP) [**Chart 2**] versus depth of burial (cm). The radiocarbon ages from the top plot were calibrated using the IntCal09 calibration curve to yield the bottom plot. Note that the uncertainty in age is nearly 10 % of Libby and Ralph's data while less than 0.5% of the AMS data. The AMS radiocarbon age yielded four calendar ages.

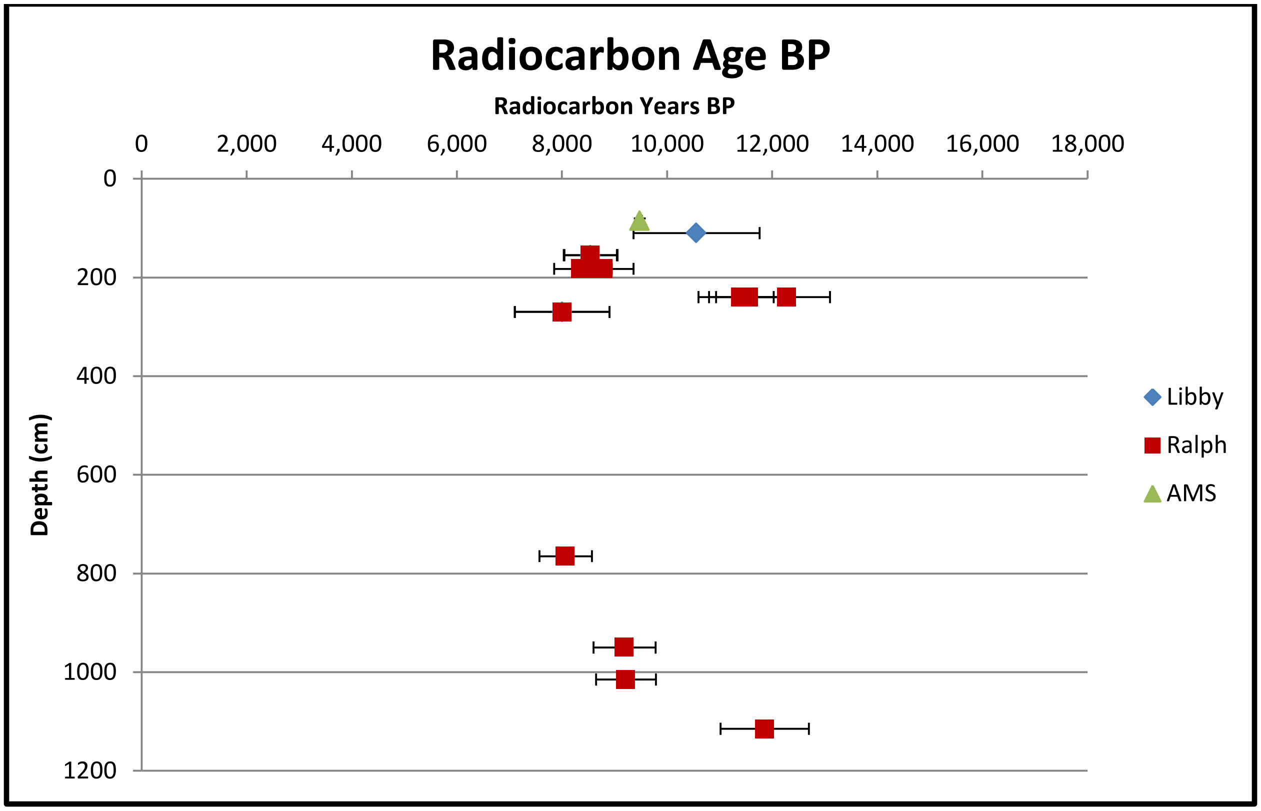


Chart 1

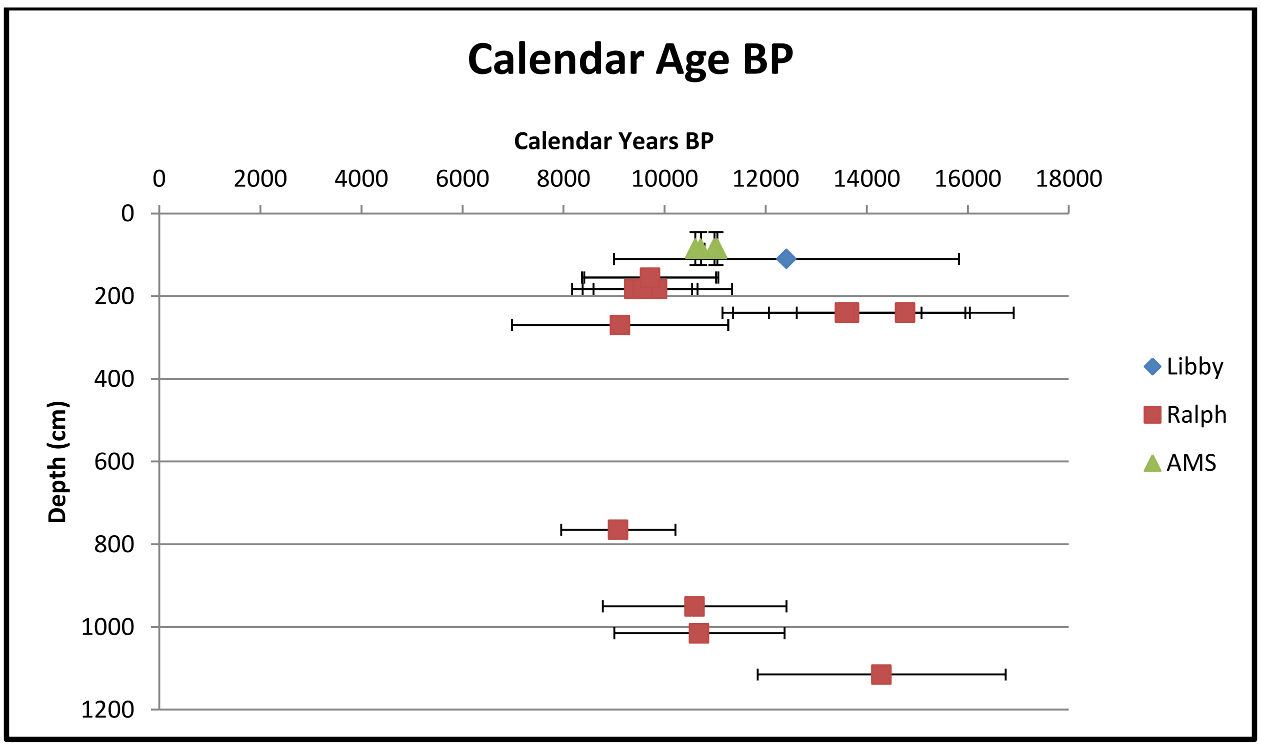


Chart 2

Discussion of the Recalibration Results

Note the large uncertainty associated with the early 1950s radiocarbon dates generated by Libby and Ralph. This uncertainty is only multiplied when a calibration curve is applied. The resulting dates span nearly the entirety of the Mesolithic and thus to do not contribute much to the absolute chronology of the Mesolithic layers. If the radiocarbon dates were accurate and precise, one would expect to see a correlation that with increasing depth, age also increases linearly, conforming to the law of superposition. However, in the radiocarbon and calendar age plots, it is difficult to find such a correlation. By using AMS to find the exact age of Skeleton #1 and considering the 2-sigma error, the relative chronology of the caves can be organized around and referenced to one certain, specific date. Thus, it is possible to say with a 95 percent confidence that Skeleton #1 dates to 10,610 ± 10, 10,720 ± 70, 10,985 ± 15, and 11,045 ± 15 calendar years BP. It follows that the overlying sediments are younger than Skeleton #1 and that Skeletons #2 and #3 are older than Skeleton #1. The degree of uncertainty yielded by the AMS data (± 10 to ± 70 years) is miniscule and in fact two orders of magnitude less than the uncertainty produced by Libby and Ralph's early work (up to ±1,680 years).

Radiocarbon Dating a Hominin Bone Sample with Accelerator Mass Spectrometry

Libby dated charred animal bones; Ralph dated charcoal deposits. In order to generate an age for the hominin bones from Hotu and Belt Caves, I posited that it would be best to actually date the hominin bones themselves. Michael Gregg and his associates attempted to do just this, but had no success. My focus was to date samples from Skeletons #2 and #3, which directly overlaid a charcoal hearth. This hearth was dated to 9,190 ± 590 BP by Ralph in 1955. However, Ralph noted that the date did not seem feasible and was most likely contaminated by overlying younger organic deposits. By extracting the bone collagen from the skeletons, it would be possible to get a relatively uncontaminated carbon sample. However, Coon and his colleagues used a "strengthening solution" in the field. The unidentified compound was painted and even poured over skeletal remains *in situ*. No records exist on exactly what compounds were used or even which bones received this treatment. Upon close examination in the lab, it was found that the sample from Skeleton #2 was completely covered with clear glue like substance which had also percolated into the bone matrix. It is possible to perform a solvent extraction to remove this outer seal, yet it is an expensive procedure and only applicable for petroleum based compounds. More analysis would have to be conducted to ascertain exactly what was painted onto the bones, and is outside the scope of this project. Thus, the desired bone samples were deemed unfit for dating.

It was decided that a tooth would be dated instead, since it is possible to scrape off surface deposits and also perform a solvent extraction and extract organic material from the sealed dentin. Mesolithic male Skeleton #1 (53-22-84) was selected, due to its mostly intact mandible and dentition. Skeleton #1's teeth were also less worn than the other plausible sample choices; some of the other remains had exposed dentin cavities due to extreme tooth wear.

The lower left canine was extracted and sent to the lab. Again, an unknown treatment had been applied to this sample. However, given the integrity of the jaw, it is most likely that the treatment was applied in the museum by a conservator in order to seal the remains rather than a strengthening solution applied in the field to safely remove it from the matrix. Historically, the Penn Museum most often used polyvinyl acetate as a sealer. It is possible to remove the polyvinyl acetate via the alkali solvent extraction technique. This extraction was preformed, the outer surface of the tooth enamel was ground off, and the collagen was extracted with an alkali solution and then radiocarbon dated by AMS. Sufficient organic material for analysis was extracted. Nitrogen isotope analysis was also completed via AMS.

Sample Preparation and Analysis Procedure

Because Ralph dated the charcoal hearth found below Skeletons #2 and #3 from Hotu Cave, it was determined that these would be the ideal skeletons to sample so that the modern AMS date could be compared to the radiocarbon results from the early 1950s. A metacarpal was selected from Skeleton #2 and mailed to Beta Analytic. Upon microscopic examination, it was determined that an unknown glue-like substance had been applied to and percolated into the bone. The Deputy Director of Beta Analytic advised that a different sample should be selected, one without a coating or one in which the coating could be easily extracted, like a tooth. **Figure 7** and **Figure 8** on the following page are close-ups of the coated bones. The glossy appearance is caused by the unknown coating.

Figure 7

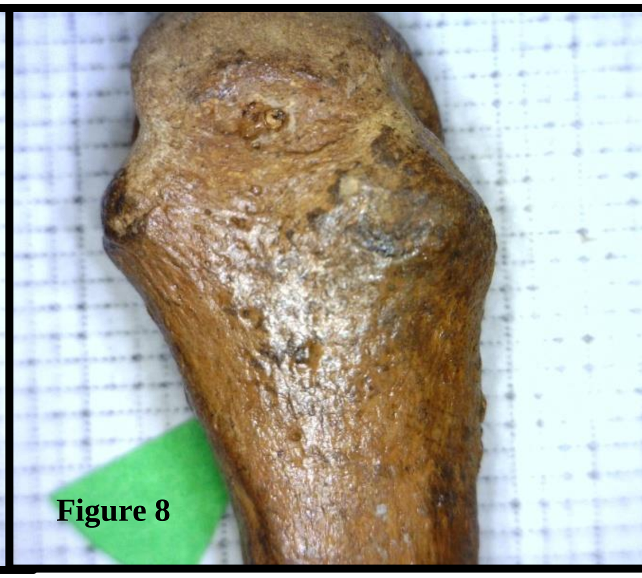


Figure 8

After collaboration with Ronald Hatfield, Deputy Director of Beta Analytic, Hotu Skeleton #1 (53-22-84) was chosen to be sampled. A lower canine tooth was carefully extracted at the Penn Museum, and then mailed to Beta Analytic. **Figure 9** at rigth shows the tooth still in the mandible of the Mesolithic male Skeleton #1.

Figure 9

The sample was analyzed by lab technicians at Beta Analytic. An unknown clear coating on the tooth was observed, and assumed to be polyvinyl acetate from conservation performed by Museum curators. It was determined that a solvent extraction would be sufficient in removing the polyvinyl acetate coating.

A solvent extraction was performed to remove any petroleum based coatings from the surface. Successive baths of benzene, toluene, hexane, pentane, and acetone were applied in order to dissolve the polyvinyl acetate surface coating.

The sample was tested for friability to determine if sufficient collagen was present. It was determined that sufficient collagen was present for extraction.

The sample was washed in de-ionized water.

The outermost surface layers were carefully scraped off of the sample.

The sample was crushed and washed in successive cold, dilute hydrochloric acids and an alkali solution of sodium hydroxide baths in order to dissolve the mineral component of the bone (apatite, calcium phosphate). The hydrochloric acid targets the bone mineral and the sodium hydroxide targeted any extraneous secondary organic acids present in the sample. One final hydrochloric acid wash was performed to neutralize any remaining alkali solution.

The collagen was extracted from the solution and examined for contamination. Any remaining mineral portions were treated in the same manner described above until they were completely dissolved. **Figure 10** at right shows the extracted bone collagen in a test tube.

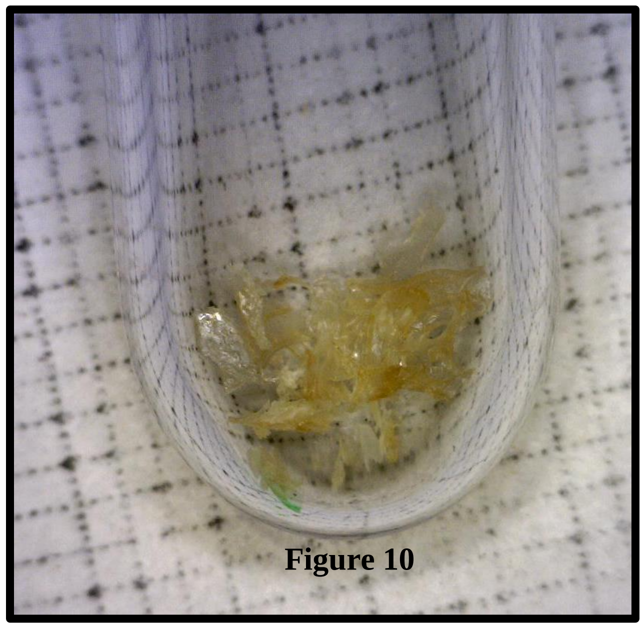


Figure 10

Sufficient collagen was extracted to perform AMS. The collagen was then analyzed via accelerator mass spectrometry. Carbon isotopes (C13/C12) and nitrogen isotopes (N15/N14) were measured. The carbon results were then calibrated using the INTCAL09 calibration database.

Budget

Table 1, below, details the expenses associated with AMS lab fees at Beta Analytic.

Analysis of 2 samples (Skeletons 2 and 3)	$100.00
Radiocarbon AMS of 1 sample (Skeleton 1)	$595.00
Solvent extraction of 1 sample (Skeleton 1)	$185
Collagen extraction of 1 sample (Skeleton 1)	$90.00
15N/14N Ratio for 1 sample (Skeleton 1)	$65.00
Return Shipping Fees	$11.47
Total Fees	**$1,046.47**

Results

Number of Individuals Found at Hotu and Belt Caves

Site	Total # of Unique Individuals	Total # of fairly complete individuals	# individuals represented by fragment only
Belt	**3**	**3**	**0**
Hotu	**5**	**3 (#s 1-3)**	**2 (#'s 4-5)**

Table 2

Hotu Skeleton #1 (53-22-84) Data Collected

Table 3, (next page) shows the skeletal measurements collected for Hotu Skeleton #1 (53-22-84). The measurement numbers (e.g. 41, 45, 46, etc) correspond to the numbers given by Buikstra and Ubelaker's 78 diagnostic measurements (1994). Only the measurements that could be accurately take are shown; although the skeleton is fairly complete, quite often one or the other distal end of the bone was smashed, missing, or poorly reconstructed, rendering an accurate and precise measurement impossible. Due to time contstrainst, I have focused the analysis on Skelton #1 because it was the specimen that was sampled and radiocarbon dated. The measurements have been separated into left and right, meaning which side of the body it came from is there are two of the same bones; if the measurement does not have a left/right side component, it is placed into the left category.

Measurements:	41	45	46	47	49	50	56	57
53-22-84 LEFT	64.57	258	12.4	15.79			204.84	149.71
LEFT, 2nd measure	64.26	259	12.92	15.58			204.75	150.28
LEFT, average	64.415	258.5	12.66	15.685	0	0	204.795	149.995
53-22-84 RIGHT					20.15	12.1		
RIGHT, 2nd measure					20.48	12.54		
RIGHT, average	0	0	0	0	20.315	12.32	0	0
Measurements:	**58**	**59**	**63**	**64**	**65**	**71**	**77**	**78**
53-22-84 LEFT	81.3	81.9				52	88.76	45.01
LEFT, 2nd measure	84.81	80.74				52	88.59	44.54
LEFT, average	83.055	81.32	0	0	0	52	88.675	44.775
53-22-84 RIGHT			50.19	27.68	37.75			
RIGHT, 2nd measure			50.37	27.83	37.67			
RIGHT, average	0	0	50.28	27.755	37.71	0	0	0

Table 3

Table 4, below, shows the measurement number and associated description, according to Buikstra and Ubelaker (1994).

Measurement #	Description
41	Humerus: Epicondylar Breadth
45	Radius: Maximum Length
46	Radius: Anterior-Posterior (Sagittal) Diameter at Midshaft
47	Radius: Medial-Lateral (Transverse) Diameter at Midshaft
49	Ulna: Anterior-Posterior (Dorso-Volar) Diameter
50	Ulna: Medial-Lateral (Transverse) Diameter
56	Os Coxae: Height
57	Os Coxae: Iliac Breadth
58	Os Coxae: Pubis Length
59	Os Coxae: Ischium Length
63	Femur: Macimum Head Diameter
64	Femur: Anterior-Posterior (Sagittal) Subtrochanteric Diameter
65	Femur: Medial-Lateral (Transverse) Subtrochanteric Diameter
71	Tibia: Maximum Distal Epiphyseal Breadth
77	Calcaneus: Maximum Length
78	Calcaneus: Middle Breadth

Angel's Skeleton #1 Measurements

The following data in **Table 5** below was collected from Angel's 1952 publication.

Measurement Description	Measurement
Projected Height of Individual	175.7 cm
Radius length	261 mm
Palate dimensions	59 x 64 mm
"Chin" (no other description of measure)	35 mm

Table 5

Accelerator Mass Spectrometry Data

Table 6 below shows the measured radiocarbon age, the carbon and nitrogen isotope rations, and the raw measured radiocarbon age, which is the corrected using delta C13 to account for isotopic fractionation. Note that "o/oo" denotes per mil, not per cent. **Table 7** below shows the calibrated and corrected calendar ages produced from the one radiocarbon age.

Table 6 Lab Number	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age (corrected for isotopic fractionation w/ δ 13C)	15N/14N Ratio
Beta - 344447 (Hotu532284)	9340 ± 40 BP	-16.6 o/oo	9480 ± 40 BP	+11.2 o/oo

2 Sigma (95%)	
Calendar Years BP	±
11045	15
10985	15
10720	70
10610	10

Table 7

Table 7 at left shows the 2 sigma calibrated dates in Calendar Years BP.

Figure 11 (next page) shows the calibrated age of the sample, including the 1 and 2 sigma error.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-16.6:lab. mult=1)

Laboratory number: **Beta-344447**

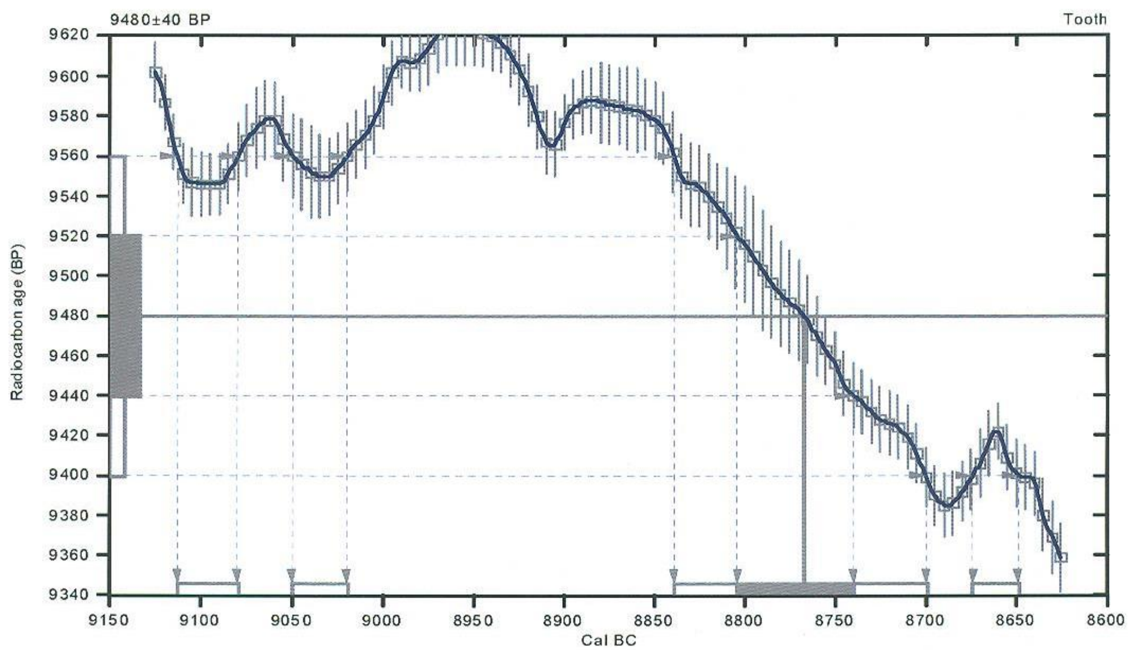
Conventional radiocarbon age: **9480±40 BP**

2 Sigma calibrated results: **Cal BC 9110 to 9080 (Cal BP 11060 to 11030) and**
(95% probability) **Cal BC 9050 to 9020 (Cal BP 11000 to 10970) and**
Cal BC 8840 to 8700 (Cal BP 10790 to 10650) and
Cal BC 8670 to 8650 (Cal BP 10620 to 10600)

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 8770 (Cal BP 10720)

1 Sigma calibrated result: Cal BC 8800 to 8740 (Cal BP 10750 to 10690)
(68% probability)



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A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory
4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

Figure 11

Interpretation of the AMS Data

Although only one radiocarbon date was generated due to the limitations of the collection and the project budget, this date can be considered the most reliable out of all of the dates that have been generated for Hotu and Belt Caves. Beta Analytic is a fully accredited and well respected laboratory. The range of uncertainty is on the order of decades, unlike Libby and Ralph's data, which have uncertainties ranging from centuries to millennia.

Figure 12 at right (modified from Walker 2005) at right shows the one radiocarbon age measured for Hotu Skeleton #1 and the calibrated calendar ages associated with that one radiocarbon date. As previously discussed, radiocarbon years are not the same as calendar years; radiocarbon dates can often yield more than one calendar date, especially during the period of 9-11,000 years BP, which is the exact time that Hotu Skeleton #1 was living on the shores of the Caspian Sea.

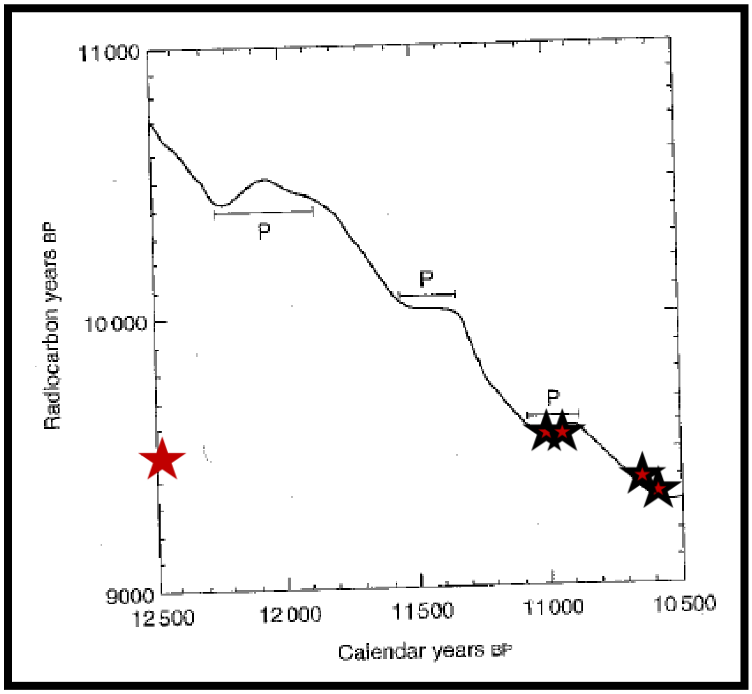

Figure 12

Interpretation of Nitrogen Isotope Ratio Results

Skeleton #1 from Hotu has a measured delta 13C value of -16.6 o/oo and a delta 15N value of +11.2 o/o. According to the work done by Tykot on isotopes and diet, Skeleton #1 most likely subsisted on a diet of mainly marine mammals and fish. This makes logical sense, as Hotu Cave is located on the banks of the Caspian Sea, an inland brackish water body. However, the isotope values lie slightly outside of the marine mammals and fish defined range; it is likely the Skeleton #1 also ate some terrestrial plants and possibly hunted and ate some terrestrial animals. Farming did not begin until the Neolithic, but a certain amount of terrestrial foraging certainly contributed bulk to Skeleton #1's diet. **Chart 3** (next page), derived from Figure 10-2 in Tykot 2006, page 134, shows the isotopic ratio analysis for Skeleton #1 and corresponding diet.

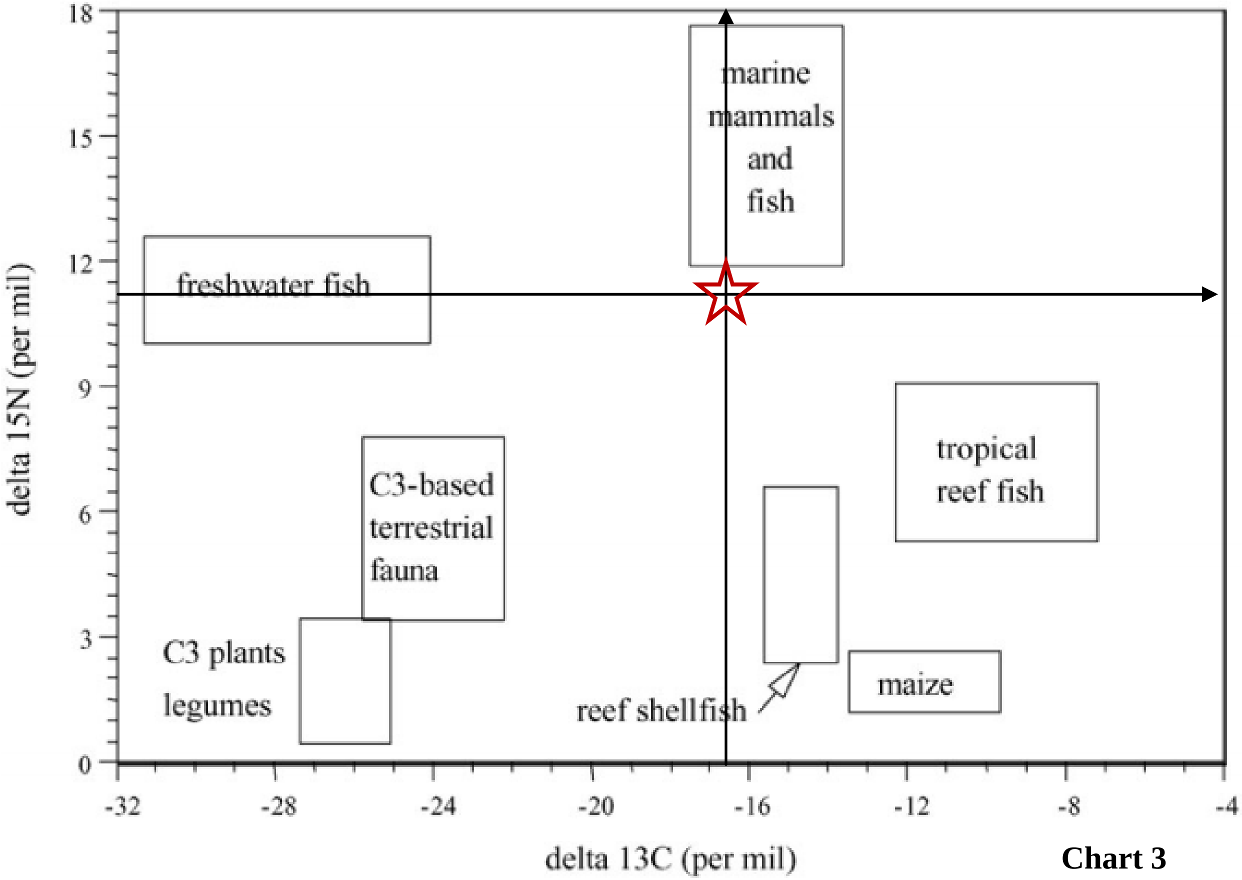

Chart 3

Discussion and Critical Assessment of the Data

Given the problems with unknown coatings applied to the bones during the excavation in Iran and during conservation at the Penn Museum, it is only natural to call into question the validity of the measured radiocarbon age. However, since a tooth, rather than metacarpal or metatarsal, was sampled and a solvent extraction was successfully employed, it is clear that whatever surface coating that was applied was successfully removed and did not penetrate the interior of the tooth. Thus, the radiocarbon age produced by Beta Analytic is a sound one. Beta Analytic is a fully accredit laboratory and in agreement with the set standards of the field. I have chosen to use the 2-sigma ages, in order to ensure with 95% accuracy that the age of Hotu Skeleton #1 is correct. Although only one sample from Skeleton #1 was analyzed, the degree of uncertainty for the age of Skeleton #1 is on the scale of years to decades, unlike the degree of uncertainty for the ages generated by Libby and Ralph in the early 1950s, which ranges from centuries to millennia.

Given the problematic radiocarbon dating of samples that are between 9-11,000 BP, the AMS data produced and its error is acceptable. This absolute age generated for Skeleton #1 can be used to organize the relative chronologies of both Hotu and Belt Caves. Hotu Skeletons #2 and #3 were found approximately 75 cm below Skeleton #1 but still within the same gravel layer as Skeleton #1. Given the law of superposition and the undisturbed and undeformed nature of the strata in which the skeletons were found, is safe to assert that Skeletons #2 and Skeletons #3 predated Skeleton #1. Since the three skeletons were entombed within the same geologic strata, it is safe to assume that they lived during times of similar geologic depositional environments and are most likely closely cotemporaneous, to a degree.

The carbon and nitrogen isotope ratios measured by AMS are also highly accurate and reliable, as Beta Analytic is fully accredited and constantly runs calibrations and test samples. These isotope data show that Skeleton #1's diet falls slightly outside of the marine animal range, which implies that Skeleton #1 consumed mainly marine animals, but also consumed terrestrial flora and fauna when available, much in line with what is known of the hunter-gatherer diet of Mesolithic populations.

Conservation Gone Wrong

Numerous and significant errors have been made regarding the skeletal material excavated from Hotu and Belt Caves. In the field, the local workmen were not adequately supervised; notably, this resulted in the smashing of several skeletal remains, including the highly regrettable smashing of Belt Skull No. 2. Furthermore, while in the field, an unspecified "strengthening solution" was applied to many of the skeletal fragments. Some remains were so heavily coated that they became fused together and could only be removed from their context by picking up the entire block of fused bone fragments. Unfortunately, the strengthening solution chemistry was not recorded, and has seeped into many of the bones, thus rendering them unsuitable for radiocarbon dating and other chemical analyses. If funds and time allow, it would be worthwhile to perform analyses to discover what exactly the strengthening solution was comprised of, and if the strengthening solution can be removed by current solvent extraction techniques.

While at the Penn Museum, Coon lent several pieces of the skeletal collection to outside researchers, including Dr. Angel and Dr. M. T. Newman, and Dr. Theodore McCown of Berkely, CA (Angel 1952, 254; Coon 1951, 79). It seems that most of the collection was returned, yet it is possible that some fragments have gone missing. Furthermore, the remains were heavily reconstructed by Angel and possibly other researches using vinolite plastic, wire, and glue. The reconstructions at times, made daring assumptions on behalf of the conservator and have aged very poorly. Currently, the reconstructions have become exceedingly fragile and brittle. Several specimens are covered with drips of glue. Conservators at the Penn Museum also applied clear coatings to the bones, presumably polyvinyl acetate, but no records of these procedures can be found.

Additionally, there is a disconnect between the field numbers assigned to the skeletal remains, which were used in both Angel's and Coon's publications, and the six museum numbers which have been inked onto the bones themselves, presumably while in the Penn Museum. Because of the two conflicting numbering systems, individual skeletons have become disjointed. Additionally, Coon noted that he only excavated 15 unique hominin skeletons at his seven unique cave sites and all of the excavated bones were catalogued and assigned to an individual. However, today, there exists a large box within the collection that contains "miscellaneous human bones." Refer to the appendix with the Skeletal Inventory Data to see how sorry of a state the collection has been reduced to.

Alarmingly, a specimen was loaned to Dr. Gregg and his collaborators for study. After determining that the sample was not suitable for the analyses they had planned, the researchers agreed to return the unused sample, in accordance to the terms of the sample loan. The sample was promised to be returned in December 2012; as of April 2013, the sample has still not been returned. Although it is only one small bone sample, each and every skeletal fragment is important. The context and importance of that missing sample is lost when it is removed from the associated material in collection. In order to ensure that future researchers have access to the complete collection, current researchers must do their due diligence to protect the integrity of the museum collection.

If modern conservation techniques had existed and been employed in the 1950s, perhaps much of the Hotu and Belt collection would be suitable for various chemical analyses.

Conclusions

The remains analyzed from Hotu Cave are in accordance with the general metrics of *Homo sapiens* populations. However, the remains excavated from Belt Cave must be further analyzed in order to make conclusions regarding whether they belong wholly to the group *Homo sapiens*, *Homo neanderthalensis*, or rather represent a hybrid between the two species. The study of the Belt Cave hominins should be pursued in the future, as the results hold great implications for Mesolithic hominin population dynamics.

Coon assigned a date of 9,100 ± 590 BP to Hotu Skeletons 1, 2, and 3. With a 95% degree of certainty, the AMS results show that the Skeleton #1 actually dates to 11,045 ± 15; 10,985 ±15; 10,720 ± 70; and 10,610 ± 10 years BP. The AMS results from Hotu Skeleton #1's tooth shows that the remains are ≈ 2,000 years older than Coon originally believed. The age of these skeletons still falls within the generally accepted time line of the Mesolithic, but adds a much clearer resolution to the events occurring in the Near East at that time. Upon closer examination, Hotu Skeleton #1 appears to exhibit strong *Homo sapiens* characteristics. Thus, I accept original hypothesis that*: The skeletal remains are that of a Mesolithic* *<u>Homo sapiens</u>* *population that are between 8-11,000 years old.* By using modern AMS techniques, it has been possible to determine, with a 95% degree of certainty, the age of Hotu Skeleton #1 within a few decades.

Questions that Remain and Recommendations for Further Research

The remains from Belt Cave are still inconclusive. Belt Skull No. 2 has a strange mixture of Neandertal and Human traits that will require further analysis. The date produced for Hotu Cave can be correlated to Belt Cave, as the two caves share a highly similar stratigraphy. If time and funds allow, further analysis, both isotopic and genetic, should be conducted on all of the skeletal remains from Hotu and Belt Caves. Additionally, more detailed and repeated measurements should be taken of all of the hominin bones from Hotu and Belt, preferably after they have been professionally conserved and restored. Then, the measurements should be compared to comparable human and Neandertal collections. That individuals' data should be measured by a one-way ANOVA to test for variance from known collections in order to determine if any of the individuals deviate from the human average towards a Neandertal like cast of features.

On a broader scale, re-excavation of Hotu Cave and exploration of the surrounding countryside should be undertaken. It is highly probable that additional limestone caves exists on the Caspian shore; those that lie at higher elevations will most likely contain Paleolithic and even Neandertal deposits and remains. By studying more caves and more skeletal remains from this region in northern Iran, a much clearer picture of prehistoric evolution and migrations can be constructed. Interactions and potential interbreeding between *Homo sapiens* and *Home neanderthalensis* may be elucidated by further work in this area.

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<u>Appendix of Skeletal Data</u>
Skeletal Measurements

Inventory of Museum Collection

Site	**Description**	**Location**	**Condition**
?	cranium	table in 159	very well preserved
?	cranium	table in 159	fairly well preserved
?	cranium	table in 159	failry well preserved
?	cranium, child	table in 159	poorly preserved, crumbling
Hotu, Mesolithic	cranium, adult female (?)	wooden tray85/2, second shelf on cart	well preserved, some plastic reconstruction of zygomatics, nasal, temporals, and parietals. Completely reconstructed left mandibular condyle
Hotu (?)	canium, child	wooden tray85/2, second shelf on cart	fairly well preserved, reconstructed, missing left lower orbit and both zygomatics, base of skull broken
Hotu, Mesolithic	cranium fragments, adult	wooden tray85/2, second shelf on cart	fragmentary, reconstructed
Hotu, Mesolithic	mandible	wooden tray85/2, second shelf on cart	fragmentary, reconstructed
Hotu, Mesolithic	fragment of left palatine and 2 premolars, child (?)	wooden tray85/2, second shelf on cart	
Hotu, Mesolithic	fragment of pelvis	wooden tray85/2, second shelf on cart	fragmentary, reconstructed
Hotu, Mesolithic	post cranial skeletal fragments	wooden tray85/2, second shelf on cart	fragmentary, some reconstructions
Hotu, Mesolithic	2 rib fragments	wooden tray85/2, second shelf on cart	broken at distal ends
Hotu, Mesolithic	post cranial skeletal fragments	wooden tray85/2, second shelf on cart	failry well preserved
Hotu, Mesolithic	post cranial skeletal fragments	box on wooden tray 85/2	farily well preserved

Hotu, Mesolithic	cranium, adult female (?)	wooden tray82/1	fragmentary, reconstructed poorly
Hotu, Mesolithic	post cranial skeletal fragments	wooden tray82/1	fragmentary, partially reconstructed
Hotu, Mesolithic	right femur	wooden tray82/1	
Hotu, Mesolithic	mandible	wooden tray82/1	fairly well preserved
Hotu	mandible fragment	wooden tray82/1	partial
Hotu	2 mandible fragments	wooden tray82/1	partial
Hotu, Mesolithic	24 vertebrae, adult female (?)	big box on wooden tray82/1	fairly well preserved, some reconstruction
Hotu, Mesolithic	2 clavicles and arroted foot bones	small box on wooden tray82/1	partial
Belt?	partial remains of young child, first premolar present, second and third premolars visible in crypts	other small box on wooden tray82/1	
Belt	Belt Skeleton screen dirt	Yoplair 150 cherry yogurt cup	
Belt	Belt Skull #4 screened dirt	Anderson Erickson Plain Lowfat Yogurt cup	screened dirt
Belt	Belt #6 humerus	blue/gray unmarked box	three pieces
Belt	skeletal fragments	blue/gray unmarked box	
Belt	cranial fragments	blue/gray unmarked box	
Belt	long bone fragment	blue/gray unmarked box	
Belt	sternum	blue/gray unmarked box	
Belt	right and left femoral condyles	blue/gray unmarked box	fragments
Belt		blue/gray unmarked box	

Belt	left tibia, talus, calcaneous	blue/gray unmarked box	fragment
Belt	3 rib fragments	blue/gray unmarked box	
Belt	2 radius fragments	blue/gray unmarked box	
Belt	2 ulna fragments	blue/gray unmarked box	
Belt	1 calcaneous fragment	blue/gray unmarked box	
Belt	1 clavicle fragment	blue/gray unmarked box	
Belt	metatarsal and phalanx	blue/gray unmarked box	
Belt	pelvis fragments	blue/gray unmarked box	
Belt	scapula fragments	blue/gray unmarked box	
Belt	head of femur	blue/gray unmarked box	some accretions on surface
Belt	9 pieces	blue/gray unmarked box	
Belt	25 pieces, 17 body fragments	blue/gray unmarked box	
Belt	right femoral condyles and patella	blue/gray unmarked box	
Belt	concreted together	blue/gray unmarked box	
Belt	8 pieces…	blue/gray unmarked box	
Belt	fragment of right illium	blue/gray unmarked box	
Belt	left navicular, left medial, intermediate, and lateral cuneiforms present	blue/gray unmarked box	
Belt	4 pieces	blue/gray unmarked box	
Belt	1 chunk of bones…	blue/gray unmarked box	
Belt	6 pieces of shaft, partial proximal end	blue/gray unmarked box	

Belt	fragment of left illium	blue/gray unmarked box	
Belt	21 fragments total	blue/gray unmarked box	
Belt	20 fragments total	blue/gray unmarked box	
Belt	fragments of teeth and bone	blue/gray unmarked box	
Belt	1 cranial fragment, 1 other fragment	blue/gray unmarked box	
Belt	3 fragments	blue/gray unmarked box	unidentified…
Belt	3 fragments	blue/gray unmarked box	
Belt	12 phalanges	blue/gray unmarked box	
Belt	4 phalanges	blue/gray unmarked box	
Belt	1 1st row phalanx	blue/gray unmarked box	
Belt	14 fragments	blue/gray unmarked box	
Belt	8 fragments	blue/gray unmarked box	
Belt	2 complete patellas	blue/gray unmarked box	
Belt	right scaphoid	blue/gray unmarked box	
Belt	right trapezium	blue/gray unmarked box	
Belt	right talus, navicular, cuboid	blue/gray unmarked box	
Belt	left scaphoid	blue/gray unmarked box	
Belt	left lunate	blue/gray unmarked box	
Belt	1 fragment	blue/gray unmarked box	
Belt	distal end of radius	blue/gray unmarked box	
Belt	5 scapula fragments	blue/gray unmarked box	
Belt	4 rib fragments	blue/gray unmarked box	
Belt	2 unidentified	blue/gray	

	fragments	unmarked box	
Belt	17 phalanges	blue/gray unmarked box	
Belt	33 unidentified fragments	blue/gray unmarked box	
Belt	right tibia shaft and distal end	blue/gray unmarked box	
Belt	9 pieces	blue/gray unmarked box	
Belt	13 pieces of well worn teeth and bone	blue/gray unmarked box	
Belt	2 pieces	blue/gray unmarked box	
Belt	2 pieces	blue/gray unmarked box	