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## The Morphology of the Axillary Border of the Scapula With Special Reference to the Neandertal Problem

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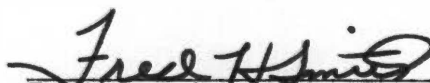
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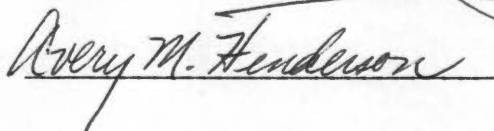
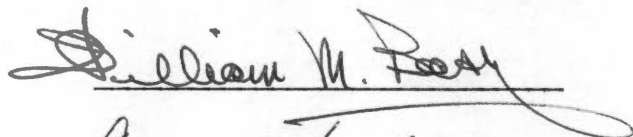
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and recommend its acceptance:



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THE MORPHOLOGY OF THE AXILLARY BORDER OF THE SCAPULA WITH  
SPECIAL REFERENCE TO THE NEANDERTAL PROBLEM

A Thesis  
Presented for the  
Master of Arts  
Degree  
The University of Tennessee, Knoxville

Carol B. Dittner

June 1976

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## ABSTRACT

Controversy concerning Neandertal man's place in anatomically modern man's ancestry continues today, 120 years after the discovery of the first Neandertal at Dusseldorf. The major emphasis of this controversy concerns the cranium. In the postcranial material, however, there are two areas which exhibit morphological differences from modern man, all other postcranial features being within the ranges of variation of modern man. These two different postcranial features are: the morphology of the superior pubic ramus of the innominate and the morphology of the axillary border of the scapula. This thesis is concerned with the latter feature.

While the axillary borders of modern men commonly exhibit a ventral groove, two-thirds of the known Neandertal scapulae where the axillary border is preserved exhibit a dorsal groove. The remainder of those Neandertal scapulae where the axillary border is preserved exhibit a double sulcus, or bisulcate pattern. This latter type was first noted on the axillary border of the Upper Paleolithic specimen from Chancelade. This Chancelade-type morphology occurs much more frequently in Upper Paleolithic hominids than in modern populations. The ventral or modern type is seen in one Upper Paleolithic specimen and has never been seen with certainty among Neandertals.

The purpose of this thesis is to test hypotheses concerning the changes on the axillary borders of scapulae between Neandertal and modern man. Comparative material used in this study was drawn from skeletal material of Arikara American Indians which are housed in the Osteological Laboratory of the Department of Anthropology at the University of Tennessee, Knoxville.

Correlations between various scapular axillary border morphologies with respect to age, sex and side were sought. Relationships between the various axillary border morphologies and the angle of the glenoid fossa, as well as the index of the glenoid fossa, were tested, but consistent correlations were not found. Positive correlations were found between the robusticity of the infraglenoid tubercles and axillary border morphologies, as well as between border morphologies and associated humeral head indices and humeral head angles.

The results of this investigation suggest that the morphology of the axillary border of the scapula is a function of use. The incidence of the Chancelade type is generally greater with advancing age and on the right side. This indicates ontogenetic causes for the varying morphologies. Correlations between varying morphologies and humeral head indices and head/shaft angles indicate that varying scapulo-humeral relationships influence the morphology of the axillary border of the scapula. In Neandertals, the barrel-shaped thorax appears to have resulted in scapulohumeral musculoskeletal relationships in the shoulder area which could have caused greater stress to be exerted on the teres minor muscle, thus creating the dorsal groove on the axillary border of the scapula.

It is suggested that the differences in morphological patterns on the axillary border of the scapula found between Neandertal and modern man can be functionally explained by (1) differences in the scapulohumeral relationship, and (2) greater biomechanical stress in the shoulder area of Neandertals than that of modern man due to the difference in cultural adaptations.



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## CHAPTER I

### INTRODUCTION

#### I. INTRODUCTION TO THE PROBLEM

In the 120 years since Schaffhausen reported the discovery of the first skeletal remains of Neandertal man near Dusseldorf, Germany, there has been both great interest and controversy among paleontologists concerning the evolutionary significance of this form to the lineage of modern man (Brace 1964, Vallois 1958). The major part of this controversy has focused on features of the Neandertal cranium (Brace 1964, Howell 1957, Brose and Wolpoff 1971). Only limited studies have been undertaken dealing with features of the postcranial skeleton. The purpose of this thesis is to investigate one of the more interesting postcranial characteristics, the form of the axillary border of the scapula (Stewart 1962a, McCown and Keith 1939, Vallois 1932, von Eickstedt 1925).

A word must be said at the start about the confusion in the use of the term "Neandertal." Originally designating only the type specimen found near Dusseldorf, the usage has been extended to include fossil specimens found in various parts of the world during the time period between approximately 150,000 to 35,000 years ago. These specimens are found in Europe, Western and Eastern Asia, South and East Africa, and Java. Some have suggested the term should apply only to those specimens found in Western Europe during Würm I (LeGros Clark 1964, Howells 1973). For the purpose of this work, the type found only in Western Europe during Würm I will be referred to as "Classic Neandertals" or "Western

European Neandertals," and "Neandertal" will be used to refer to all skeletal material from this time period regardless of geographic location.

Various hypotheses or schemes exist with regard to the relationship between Neandertal man and modern man. One of the earliest schools of thought, which still has a few adherents, is the pre-Sapiens hypothesis. Boule (1921) propagated this concept (also reflected by his student, Vallois 1958), which states that all Neandertals were merely the end-product of a completely separate side branch of hominids, coexistent with, but independent of, that branch leading to modern *Homo sapiens*. The roots of the lineage to modern *Homo sapiens* began with the Swanscombe specimen from the Holstein Interglacial. Specimens from Fontchevade, dated to the Eemian Interglacial, supposedly possess only sapiens characteristics. Heidelberg, Steinheim, and Ehringsdorf, all of which have characteristics similar to the later Würm Neandertals, are regarded as the predecessors of Würm Neandertals. According to the pre-Sapiens hypothesis, the Würm Neandertal lineage came to an end with the Classic or Western European Neandertals (Thoma 1965), which developed unusual morphological characteristics, especially on the cranium. Some of these characteristics include: a well-developed occipital bun, pronounced mid-facial prognathism, projecting brow ridges, long, low cranium, general robustness of the face, large nasal aperture, and short extremities on a stocky body.

A second school of thought, the pre-Neandertal school, uses the remains from Swanscombe and Steinheim as the progenitors of a Generalized or Progressive type of Neandertal found during the Eemian Interglacial

in Europe. These Generalized Neandertals supposedly developed into modern man outside of Europe, and into Classic Neandertals in Western Europe. The Classic Neandertal populations of Western Europe, including Spain, became isolated and cold-adapted as reflected in their morphology. Meanwhile, according to this theory, populations elsewhere were evolving into modern man. Among the major proponents of this theory are F. C. Howell (1951, 1952, 1957), W. W. Howells (1973, 1974), and W. E. LeGros Clark (1964). These scholars believe that the Classic Neandertals were superseded by the modern men moving into Europe from other areas, possibly from the Near East.

The *in situ* evolution from Neandertal into early modern man in Europe, as well as in other areas, is the hypothesis espoused by the Unilineal or Neandertal school. First proposed by Schwalbe (1906) and later propagated by Hrdlička (1927) and Weidenreich (1947), this theory has been revived by Brace (1962, 1964, 1967), and Brose and Wolpoff (1971). These scholars as well as those who adhere to the pre-Neandertal school, believe that the Classic Neandertals were isolated and cold-adapted. Although the robustness of the face is thought to be due, in part, to a large anterior dentition, mid-facial prognathism is considered to be more of an adaptation to the cold. Specifically, the large nasal apertures, the great height of the upper face and the forward projection of the face may have been necessary for separating the nasal passages from the brain in order for the air to be warmed before it passes near the brain (Brose and Wolpoff 1971). It is maintained by the Unilineal school that there was a sufficient time interval between the Classic Neandertals and the more anatomically

modern men of the subsequent Upper Paleolithic period for *in situ* evolution to have occurred. Thus the Unilinealists believe that there was a direct and gradual transition between the Neandertal and early modern man in Europe and that an influx of more modern hominids is not necessary to explain the changes.

That the controversy over Neandertal's place in our ancestry still rages may be surprising, as skeletal and cultural remains of this group have been known and studied by scientists for more than 100 years.. One of the problems in resolving this dilemma has been the paucity of significant hominid material from the crucial time period of the early phases of the Upper Paleolithic. However, old material is being re-examined in the light of new dates and a better understanding of skeletal biological variability.

The image that Boule created of Neandertal man from his study of the La Chapelle-aux-Saints postcranial and cranial remains (1911/13) is now considered to be false. Straus and Cave (1957) found no evidence, for example, that Neandertal spinal columns lacked the convexities necessary for fully erect posture. In addition, Stewart (1962b) concluded from his studies on cervical vertebrae of Neandertals that there was no basis for Boule's contention that Neandertal man's head was slung forward on a short and thick neck. Thus, the postcranial remains of the Classic and other Neandertals are now considered to be essentially like those of modern man except for more robusticity, as exhibited by such features as the wide epiphyses of the long bones, relative thickness of the hand and foot bones, and relative stoutness of the ribs (Howell 1957).

The frontal bone from Velika Pečina, dating to  $33,850 \pm 520$  B.P. (Smith 1976a) and the establishment of early dates for Predmost and Brno of the early Upper Paleolithic (Jelinek 1969) help to fill some chronological and geographical gaps in the fossil record. In addition, the archeological data are beginning to demonstrate the ". . . slow cultural change of the Middle Paleolithic Mousterian into . . . the Upper Paleolithic" (Mann and Trinkaus 1973:188). Thus, while there is still a need for further information, the cultural and biological boundary between Neandertals and modern man in Europe appears to be deteriorating.

Turning to the postcranial morphological differences between Neandertals and modern man, specifically in the hands and thorax, such features as the greater transverse width of the heads of thumb metacarpals and the relatively short length of distal phalanges demonstrate that the Neandertal hand was a squat, powerful appendage (Musgrave 1971). Any of these features *can* be found in modern hands, but rarely occur jointly in one hand (Musgrave 1971). The Neandertal thorax differs from modern man's in that the ribs are thicker and less curved (McCown and Keith 1939, Hrdlička 1930, Endo and Kimura 1970, Heim 1974, Smith 1976b). In accord with this morphological pattern of the ribs, the clavicles of Neandertals are typically strongly curved. These features suggest that the Neandertal thorax was barrel-shaped (Hrdlička 1930, McCown and Keith 1939). Heim (1974) in his study of the La Ferrassie postcranials pointed out that in spite of the differences discussed above, Neandertal postcranial remains differ little from those of modern men.



On the other hand, there are two postcranial areas where the anatomical features of Neandertal man are outside the range of variation for modern man. One of these is in the thinning and elongation of the superior pubic ramus of the innominate bone. McCown and Keith (1939) first noticed this peculiar morphology in the pelvis of the Tabun woman from Mount Carmel and wrote that it appeared to distinguish her from the Skhul population, as well as from that of modern man. Stewart (1960) also reported this peculiar thinning and elongation of the superior pubic rami in Shanidar I and III. As both of these Shanidar specimens appear to be males, it was concluded that the peculiarity was probably not due to sexual differences. Amud I, another male, also exhibits this morphology (Endo and Kimura 1970).

This thinning and elongation of the superior pubic ramus was recently studied in the remains of the La Ferrassie I and Krapina 208 innominates, and compared to the previously studied Southwest Asian Neandertals (Trinkaus 1976). It appears that the supero-inferior flattening of the ramus is a secondary result of the elongation of the ramus from acetabulum to symphysis. Both features are more pronounced among the Southwest Asian Neandertals than among the European Neandertals. However, no functional explanation for this distinctive morphological patterning has been forthcoming. Although there is greater elongation of pubic bones in modern females than in modern males (Bass 1971), the sampling of Neandertals available is thought to be of both sexes, thus negating any theory involving sexual differences. This idea of sexual differences as well as the possibility of biomechanical alterations, e.g., hypertrophy and/or atrophy, as an explanation, has also been investigated and abandoned by Trinkaus (1976).

The second exceptional skeletal area of Neandertals is the morphology of the axillary border of the scapula. It has been noted by several workers (Vallois 1932, von Eickstedt 1925, McCown and Keith 1939, Stewart 1962a, Endo and Kimura 1970, Smith 1976b) that the axillary border of the scapulae of Neandertals normally exhibits a different morphological pattern than is usually exhibited in modern man.

### *The Modern Type*

Looking at the axillary border of the scapula of modern man in its lateral aspect, one sees that a crest normally descends from behind and below the infraglenoid tubercle caudally toward the inferior angle (Figure 1). In most modern hominids, a groove is formed ventrally when the crest, which extends from behind and below the infraglenoid tubercle, descends on the dorso-lateral aspect of the border. A longitudinal buttress or bar of bone rises on the ventral portion of the border which forms the ventral lip of the groove. In this case, a gutter is formed on the ventral aspect of the border, the opposite direction of the Neandertal type. This gutter extends caudally for two-thirds of the border and deviates dorsally several millimeters before the teres process, where it ends. The groove is most often called simply the ventral groove or gutter, but may be called *sulcus ventro-axillaris* (Stewart 1962a), *sulcus axillaris subscapularis* (von Eickstedt 1925) or *facies ventro-axillaris* (Vallois 1932).

### *The Neandertal Type*

In a typical Neandertal scapula (Figure 2) the axillary crest veers off to join with the ventral buttress of the axillary border,

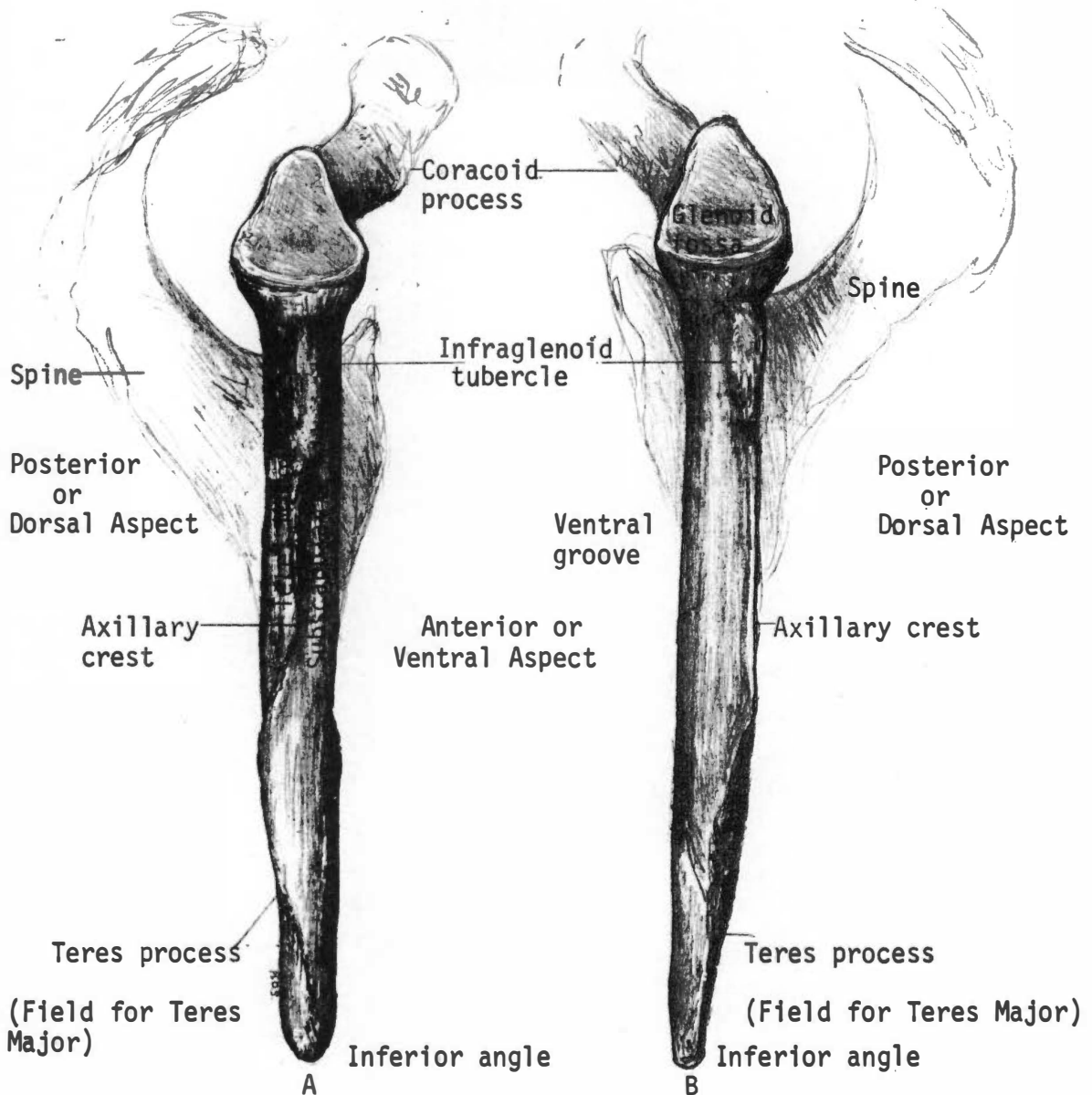


Figure 1. Morphologies of the axillary border of the scapula in modern men. On the left (A) the Chancelade or bisulcate type. This pattern has two narrow sulci on either side of the medially placed axillary crest. On the right (B) is the ventrally grooved border which is found in the majority of modern men. Both scapulae are from modern *Homo sapiens*.

Drawings courtesy of Maria O. Smith.

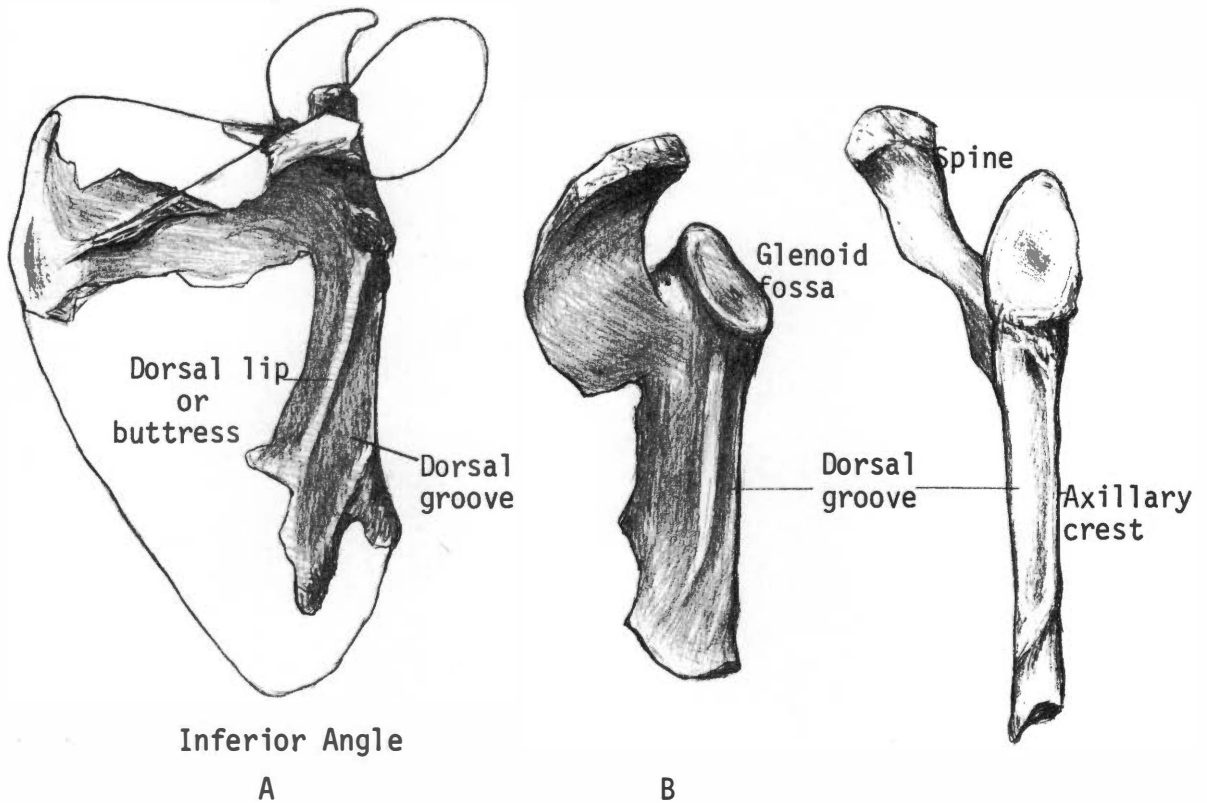


Figure 2. Right scapulae of La Ferrassie I (A) and of the original Neandertal from Dusseldorf (B) in dorsal-lateral views. (left to right). Both scapulae have the *sulcus dorso-axillaris* or the Neandertal type border. From Stewart (1962a, Figures 3 and 4).

thus forming a pronounced groove on the dorsal aspect of the bone. A bar or buttress of bone rises longitudinally on the dorsal aspect of the border forming the dorsal limit of this axillary gutter or groove. The groove and the buttressing pillars extend two-thirds of the length of the axillary border ending at the dorso-ventral flattened area of the teres process or protuberance. Boule first described this typical Neandertal type of axillary groove on the La Ferrassie I scapulae (Boule 1911/13). Von Eickstedt (1925) named this dorsal groove *sulcus axillaris teretis* in recognition of the dorsal muscular insertion. It is also called Boule's sulcus, *sulcus dorso-axillaris*, the Neandertal type (Stewart 1962a) or *facies dorso-axillaris* (Vallois 1932).

#### *The Chancelade Type*

A third major variation of the axillary border was first described by Testut (1889) who noted this morphology on an Upper Paleolithic scapula from Chancelade. The Chancelade type (Figure 1A) has two shallow, narrow, longitudinal grooves which usually face laterally. In this type, the crest that extends below the infraglenoid tubercle descends toward the center of the border rather than joining either the dorsal or ventral pillar or buttress. Most often, the sulcus nearer the ventral side is the larger one. This border may be called the Chancelade type, the bisulcate type (Trinkaus in press), or *facies axillaris bisulcata* (von Eickstedt 1925), as well as an intermediate or mixed type of scapular border. This type is found most frequently in Upper Paleolithic specimens, but it is also found not infrequently in both modern man and Neandertals (Stewart 1962a).

## II. STATEMENT OF THE PROBLEM

From the literature it was determined that Neandertals display a distinct dorsal groove in two-thirds of the known specimens where this border is preserved, whereas the Chancelade type, wherein two shallower, narrower longitudinal sulci lie laterally on the border, is seen in approximately one-third of Neandertal scapular specimens (McCown and Keith 1939, Stewart 1962a, Endo and Kimura 1970, Smith 1976b, Trinkaus in press). On the other hand, not one adult Neandertal specimen clearly shows a border with a ventral groove (Smith 1976b). The Neandertal juveniles exhibit an indistinct groove pattern on the axillary border (Gorjanović-Kramberger 1926, Smith 1976b). Indistinctness as to morphological type is generally the case in modern juveniles as well.

This thesis involves the reinvestigation of the scapula's axillary border morphology in order to test the hypothesis that morphological differences on the border are a function of use. Employing both morphological and metrical data of Arikara American Indians, an attempt was made to determine if use may have been a factor in axillary border morphology of these hominids and ultimately to suggest why the Neandertals so frequently exhibit the dorsal groove, anomalous in modern man, and why the modern morphology is never seen in Neandertals. The question is whether there is a functional difference being reflected in the differing morphology of the axillary scapular borders of Neandertal, Upper Paleolithic and modern men.

The data gathered for this study were used to provide the following information:

1. To establish the frequency of occurrence of the various morphological types on the axillary border of the scapula in the Arikara sample.
2. To determine if the occurrence of each particular type of morphology on the border correlates significantly with any one of the following factors:
  - a. Age--Do older people have a greater incidence of the Chancelade type than the ventral type?
  - b. Sex--Is there any greater incidence of the Chancelade type in males than in females?
  - c. Side--Do presumably right-sided people more frequently have a Chancelade morphology on the right scapula when the left is ventral. if a dichotomous situation in morphologies exists (see Figure 3)? Handedness in the skeletal material has largely been determined by noting whether the right humerus, when both were available, was longer or thicker than the left (Hrdlička 1932, 1942c). When humeri were lacking, handedness was established by noting which scapula had the greater width on the axillary border (Vallois 1932), or, all else failing, by using the presumption that about 90% of most individuals in modern populations are right-handed (Jantz 1964, Loveland 1974).

If the data showed positive results with regard to most of the factors investigated, it could be inferred that there is an ontological or functional basis to the appearance of certain morphologies on the axillary border.



Figure 3. Left-right variability seen in the scapulae of a 30-40 year old female Arikara Indian from the Larson site, South Dakota. The left scapula has an axillary border of the modern ventral type. The right has an extreme variant of the Chancelade type where the teres minor muscle insertion is more extensive than is normally seen in the bisulcate pattern.



Other characteristics of the shoulder area which somewhat differentiate Neandertal and modern man were taken into account. Intrinsic to this approach is the realization that the scapula is only one part of the shoulder area and is being acted upon by related skeletal parts. Indeed, the scapula ". . . is a necessity of and product by the muscles that radiate from it towards the spine, neck, chest and shoulder. Without these muscles there would be no call for it and it would not have come into existence. . . ." (Hrdlička 1942a:73). "The scapula in the living form . . . is suspended . . . in space by the muscles acting upon it, and it is, therefore, not surprising that this bone should reflect more clearly than any other the changes which have been brought about by more specialized functional demands" (Inman, Saunders and Abbott 1944:2). One should be aware of the differences between Neandertal and modern man that occur in the shoulder area. An attempt was made to synthesize the salient divergent features, while visualizing the interrelationships of the shoulder area, and thus to extricate the reason for the morphological changes on the axillary border of the scapula.

Differences between Neandertal and modern man in the shoulder area are:

1. The rib cage of Neandertal is different from modern man. As previously described, Neandertals are more barrel-chested than modern man. The thorax of Neandertal is more capacious than that of recent man as the ribs are less curved (Hrdlička 1930, McCown and Keith 1939, Endo and Kimura 1970. The situation in *Homo erectus*, or in other forms which preceded

modern man is unknown, as the relevant skeletal material of these forms has not yet been found.

2. The humeral head of Neandertals is slightly more cranially directed than that of modern man in relation to the axis of the shaft (McCown and Keith 1939). The head is also larger in transverse movement than in vertical movement (McCown and Keith 1939). In modern men, the vertical measurement is normally greater than the transverse.
3. The glenoid fossa of Neandertals is narrower, thus the length/breadth index is smaller. The fossa is slightly less cranially directed than that of modern man (Vallois 1932). Although the axillo-glenoid angles of Neandertals are within the upper range of the angles for modern man, nevertheless, there *is* a tendency for a more laterally directed fossa in Neandertals (Stewart 1962a).
4. The infraglenoid tubercle is more robust in Neandertals than in modern man (McCown and Keith 1939). In general, the scapulae and humeri, as all other postcranial material of Neandertals, are more robust than in modern man.

Considering the above-mentioned variations in the shoulder girdle, it is hypothesized that scapulohumeral relationships differed in the Neandertals, possibly because of the barrel-shaped chest. The altered relationships between scapula and humerus may have caused greater stress to be exerted on the teres minor muscle than is the case in modern man, thus causing its enlargement in Neandertals.

The data found in the Arikara skeletal material was used to test the hypothesis by seeking these correlations:

1. Does the Chancelade-type border in the modern sample used here correlate significantly with a narrower glenoid fossa (lower index), and/or a more laterally inclined fossa (larger angle)?
2. Does the Chancelade-type border correlate well with more cranially inclined humeral heads and/or wider humeral heads?
3. Does scapular and humeral muscularity as well as depth of fossae correlate with particular border morphologies in a significant way?

Correlations between Chancelade bordered scapulae and narrower fossae were expected. It was also expected that more muscular scapulae would be associated with the Chancelade morphologies, and that these morphologies would show a positive relationship with wider and/or more cranially deviated humeral heads (see Figure 4).

All of the data will be used to determine if a functional explanation is plausible for the differences in axillary border morphology between Neandertals and modern men. If a functional explanation seems acceptable, an attempt will be made to formulate a distinct functional explanation for this phenomena.

### III. PREVIOUS INVESTIGATIONS

In 1889, Testut first observed that the male Cro-Magnon-type skeleton from Chancelade exhibited an unusual morphology on the axillary border of the scapula. This morphological type, often referred to as



Figure 4. The scapulae of an Iranian Caucasoid male, 18-30 years of age. Both left and right are considered variants of the Chancelade type axillary border. Note the variability within this classification. The associated humeri of this specimen had high humeral head indices and high head/shaft angles.

the Chancelade type, can be described as two narrow, longitudinal sulci divided by a crest that extends caudally from the infraglenoid tubercle. Normally, the ventral sulcus is slightly larger. This type, later called *facies axillaris bisulcata* by von Eickstedt (1925), is found on 8 of the 22 known Neandertal scapulae (Table I). Among the Neandertals with this pattern are: Shanidar III and six specimens from Krapina. The Skhul specimens were all classified as Chancelade types by Stewart (1962a) and grouped with Neandertal specimens. It is not clear, however, whether Skhul hominids are truly Neandertal. Smith (1976b: 263) ". . . is reluctant to consider these specimens Neandertal. . .," as the time period of the Skhul population, 35,000 B.P., seems to make them temporally equivalent with early Upper Paleolithic hominids in Europe. Trinkaus (in press) places the Skhul specimens in a category separate from Neandertals and from Upper Paleolithic hominids, and classifies all three Skhul specimens as having the Chancelade morphology.

Among Upper Paleolithic hominids, the Chancelade type is found in Predmost III, X, and XI, Chancelade and Combe Capelle (Endo and Kimura 1970, Smith 1976b).

Von Eickstedt (1925), in classifying the variations in axillary border morphologies, considered the Chancelade type, as well as a laterally turned ventral type, as in-between or transitional "steps" between the Neandertal type and the modern. He and Vallois (1932) also considered this Chancelade type as "primitive" when compared to the morphology of modern man, maintaining that it is to be found most frequently at "primitive racial levels."

It was the famous French paleontologist, Marcellin Boule, who

TABLE I

## SPECIMENS OF NEANDERTAL SCAPULAE WHICH PRESERVE THE AXILLARY BORDER

Specimen	Side	Description
<i>Neandertal Type Axillary Border</i>		
Dusseldorf	R	2/3 axillary border, spine, glenoid fossa.
La Ferrassie I	L	Glenoid fossa, border to teres process.
Le Ferrassie II	L	Deteriorated piece
Shanidar I	L	Coracoid, base of spine, 1/2 axillary border, glenoid fossa
Tabun I	L	Glenoid fossa, border, lower angle
*Spy I and II		*Hrdlicka (1930) believes both left and right belong to Spy II.
Amud I	L	Glenoid fossa, lateral spine, medial acromion.
Krapina IX	R	Upper border, glenoid fossa, part of coracoid.
Krapina XI	L	Part of coracoid process, base of spine, glenoid fossa, upper border.
Krapina XII	R	Glenoid fossa, base spine, coracoid.
*Krapina V	L	*Smith (1976b) reclassified it as dorsal. Glenoid fossa, coracoid, base of spine.
<i>Chancelade Type Axillary Border</i>		
Shanidar III	R	Most of border, part of glenoid fossa.
Krapina VII	R	Border, fossa, spine, base of acromion.
Krapina VIII	R	Border, lower 1/3 fossa, base of spine.
Krapina X	L	Border, fossa, coracoid, base of spine.
Krapina XIII	R	Fossa, coracoid, upper border
Krapina XIV	R	Upper border, part of fossa
Krapina XV	R	Upper border.
*Krapina XIX	L	*Possibly Chancelade type (Smith 1976b). Fossa, base of spine, border.

first noticed that the morphology of the axillary border in certain Neandertal scapulae differed from the same area in both modern man and the Chancelade hominid. Boule used the scapulae from the La Ferrassie I specimen as substitutes for the missing scapulae of La Chapelle while completing his study of the skeleton from La Chapelle-aux-Saints (Boule 1911/13). Both right and left bones of La Ferrassie I exist and Boule noted that both exhibited a dorsal axillary sulcus, just the reverse of the normal condition in modern man. The dorsal groove is often referred to as Boule's sulcus (McCown and Keith 1939). The same morphology is also seen in ". . . a very deteriorated piece of one of the scapulae of La Ferrassie II. . ." (Stewart 1962a:782). The La Ferrassie material has been recently reevaluated by Heim (1974) who further elaborates on these and other scapular characteristics of this material. In addition to the La Ferrassie material, the Neandertal type border is seen on Neandertals from Dusseldorf, Shanidar I, Tabun I, Spy I and II, Amud I, and Krapina V, IX, XI, and XII (see Table I). Endo and Kimura (1970) claim that two old males of the Upper Paleolithic, Oberkassel and Predmost XIV, have the dorsal groove on the axillary border. However, Trinkaus (in press) has reevaluated these specimens (from photographs) and maintains that they have the Chancelade pattern on the axillary border.

Schwalbe (1914) synthesized the data on Testut's Chancelade type and Boule's Neandertal type and introduced the term "*sulcus axillaris*" for the groove on the axillary border of the scapula. Believing this phenomenon to be merely the movement of one sulcus which changed position over time, Schwalbe did not differentiate between different orientations

of the sulcus. This situation was somewhat remedied by Gorjanović-Kramberger (1914) who restudied and reclassified the Krapina scapulae into three groups in the light of these aforementioned discoveries. Gorjanović began to use the terms *sulcus dorso-axillaris* for the Neandertal pattern, and *sulcus ventro-axillaris* for the modern pattern.

Von Eickstedt (1925) elaborated on Gorjanović-Kramberger's differentiations by noting muscular insertions on the border and imposing the use of the names of muscles in describing the border. Thus he named the dorsal (Neandertal) groove *sulcus axillaris teretis*, observing the dorsal insertion of the teres minor muscle, and the ventral groove *sulcus axillaris subscapularis*, noting that the subscapularis muscle has partial origin in the ventral sulcus. The Chancelade type, having a double groove, was called *facies axillaris bisulcata* by von Eickstedt.

Aside from clarification of terminology, von Eickstedt's purpose was to disagree with Schwalbe's contention that the sulcus had moved in the course of time. Von Eickstedt believed that there were two morphologically different structures, and not merely a "wandering around" of the sulcus from the ventral to the dorsal side of the axillary border. Von Eickstedt also believed that Schwalbe's suggestion that a new muscle had appeared dorsally was incorrect. Another area of disagreement between von Eickstedt and Schwalbe concerned Schwalbe's placement of the infraglenoid tubercle at the cranial beginning of the "*labium dorsale*" in the Neandertals. The "*labium dorsale*" is the bone strut or "lip" which dorsally confines or defines the dorsal groove. Von Eickstedt suggested that Schwalbe had misinterpreted this placement due to the amount of damage on the Neandertal specimens



available to Schwalbe. He maintains that the tubercle is actually at the start of *labium laterale* as seen in the La Ferrassie specimens used by Boule. Von Eickstedt also stated that the tubercle is at the start of *labium laterale* in a specimen with a ". . . massive dorsal visible *sulcus a teretis* on a right scapula photographed by Gorjanović-Kramberger from the Krapina remains. . ." (translated from von Eickstedt 1925:220).

Von Eickstedt stated that, although ". . . function modifies the shape of the scapula, it is not to be assumed that function is always exclusively responsible for the shape of the border as there are innate racial differences" (translated from von Eickstedt 1925:221). He surveyed scapulae of *Homo sapiens* from various parts of the world. Of 409 scapulae investigated, 26 or 6.4% exhibited the dorsal sulcus, 65 (15.6%) had a suggestion of a dorsal sulcus, 95 (31.4%) were of the Chancelade type, and 135 or 44% had the "European" or "normal" modern type (ventral sulcus). One must view these findings cautiously, however, since von Eickstedt did not make it completely clear what variations he accepted as dorsal.

Problems of exact classification also arose when Gorjanović-Kramberger once again restudied and reclassified the Krapina scapular material in 1926. Three of the 17 scapulae were said to be the Neandertal type: IX, XI, and XII; and 6 were said to be Chancelade type: VII, X, XIII, XIV, and XIX. Seven were considered as unclassifiable or uncertain. Of these 7, 5 are juveniles, which are always difficult or impossible to classify, especially if very young. Smith (1976b) restudied these scapulae and reclassified scapula V(125) as a Neandertal type, and scapula VII(127) as the Chancelade type.

The high percentage of Chancelade types at Krapina appears rather unusual as this percentage is somewhat higher than that which is found in the total Neandertal sample. Stewart (1962a) has questioned the dating of this skeletal material to the Riss-Würm Interglacial period. In all other sites, the Chancelade type is found in greater frequencies in material of the Upper Paleolithic. But Smith (1976b:265) explains that

. . . the hominid remains come from all levels of Krapina and span a time period from the end of the Riss-Würm to the Würm I/II interstadial. The stratigraphic origin of the scapulae are not yet known, and it is possible that specimens exhibiting the Chancelade type come from higher in the Krapina sequence.

In 1939 McCown and Keith studied the shoulder girdle of the specimens from Mount Carmel. The axillary borders of Tabun I, Skhul IV, V, and IX were compared with the right scapula found near Dusseldorf for its Neander-like characteristics. Among other interesting points, they noted that the proportion of the axillary border of these Palestinian specimens to the maximum length of the humerus (scapulohumeral ratio) was slightly different than in modern groups. The significance of the proportionally shorter border of the Mount Carmel specimens is not known. McCown and Keith also mentioned the dorsal inclination of the glenoid cavity of the Neandertal scapulae; and, after investigating the possibility of dorsal deflection in their material, they concluded that the Neandertal's great deflection was an extreme individual variation. Stewart's (1964) re-evaluation of this matter will be discussed later.

With regard to the axillo-glenoid angle, McCown and Keith (1939) noted that the angle in the Dusseldorf scapula ( $145^{\circ}$ ) and Krapina

scapulae ( $134^{\circ}$ - $146^{\circ}$ ) is greater than in modern men, but concluded that the Palestinian figures are not Neander-like. Tabun I has an angle of  $132^{\circ}$  and that of Skhul V is  $127^{\circ}$ . The modern range is  $120^{\circ}$ - $135^{\circ}$ , a more cranial deviation than the angle for Neandertals. With regard to the morphology of the axillary border, McCown and Keith reported that Skhul V and IX have the Chancelade type, Tabun I has a highly developed dorsal sulcus, and the preserved segment of the Skhul IV scapula appeared to have an incipient stage of a dorsal groove. Stewart (1962a) and Trinkaus (in press), however, consider all three Skhul specimens as Chancelade types. Curiously, the Mount Carmel report referred to a Krapina specimen (Number 1, right) as having a morphology ". . . as in modern scapulae" (McCown and Keith 1939:135). Smith (1976b), however, reports that none of the specimens exhibit a ventral groove. According to Smith, scapula I is a juvenile specimen, which, as has been said, are almost impossible to classify.

McCown and Keith believed the Mount Carmel scapular series bridged ". . . the gap which exists between the state found in the western European Neanderthalian and that which prevails among modern races" (1939:136). Interestingly, their viewpoint was: "The modern condition represents the old or anthropoid condition, while the marginal fossa of Neanderthal man is an evolved and later acquisition" (McCown and Keith 1939:136). In sum, the Mount Carmel scapular specimens were regarded by McCown and Keith as being of the same group as the Neandertals of Europe; although they felt moved to separate the Tabun type from the Skhul form because of the morphology of the coracoid process.

Vallois made a very thorough survey of the general features of the human scapula, commencing in 1928 and continuing in a series of publications on the scapula until 1946. Included in this was a considerable amount of information and study on the axillary border, notably the detailed descriptions of the axillary borders of three Neandertal scapulae and two Upper Paleolithic specimens (Vallois 1932). He reports that, contrary to von Eickstedt's findings, no Neandertal types are found in any modern hominids and the Chancelade type is observed only rarely. Thus, according to Vallois, the true Neandertal type is unique to Neandertals. He maintains that robust scapulae, usually those of men, have thicker borders and a well-marked ventral gutter oriented more laterally than in less robust scapulae. The teres minor surface is also larger on the scapulae of individuals with heavy muscular markings. Vallois further suggests that "exotic" races of modern men are very different from Europeans in that one more frequently finds robust morphologies in these groups. On this point, Vallois and von Eickstedt are in agreement. Von Eickstedt (1925) found most of the robust and/or Chancelade types in Bushmen and other "primitive" groups; and Vallois found the greatest number of Chancelade types in Melanesians and Australian aborigines, and rarely in the French.

Vallois sought to interpret the variations on the axillary border by considering muscle attachments. He noted that the insertion of subscapularis on the ventral surface is often by the subscapularis accessory, the most external fascies of subscapularis. As stated elsewhere, the teres minor muscle inserts on the dorsal surface of the border. As teres minor and the external fascies of subscapularis are

the stabilizers and rotators of the arms--the former to the outside, the latter to the inside--Vallois believed the Chancelade type was a result of very powerful movements of elevation of the arms. Vallois also believed it was possible that the subscapularis accessory differentiates completely from the subscapularis muscle proper; however, according to him, this point of myology was not documented. Vallois considered the Neandertal type border as less easily explained (1932). The obviously greater development of teres minor with the resulting weak development of subscapularis may be due to the movements of elevation being habitually accompanied by rotation of the arms to the outside instead of rotation to the inside as in modern man (Vallois 1932:49). Consequently, the muscle which lowers and rotates externally predominates at the cost of the muscle which lowers and rotates internally.

Vallois also studied the axillo-glenoid angle, noting that anthropoids' glenoid cavities deviate cranially ( $107^{\circ}$ - $109^{\circ}$ ) and man's, laterally ( $120^{\circ}$ - $135^{\circ}$ ). There are, however, differences in this feature among the races of modern men and Vallois considered the more cranial deviation of the Negrilles as "primitive" (see Figure 5). Although the Neandertal range of  $139^{\circ}$ - $146^{\circ}$  is dissimilar from the normal modern range, Vallois claimed that Neandertals can not be utterly distinguished from modern people either by this orientation or by a particularly dorsal orientation of the fossa.

Stewart (1962a) further discussed the relative narrowness of the Neandertal glenoid fossa, a feature cited by Vallois as a tendency among these hominids. Stewart agreed with Vallois and found a narrow

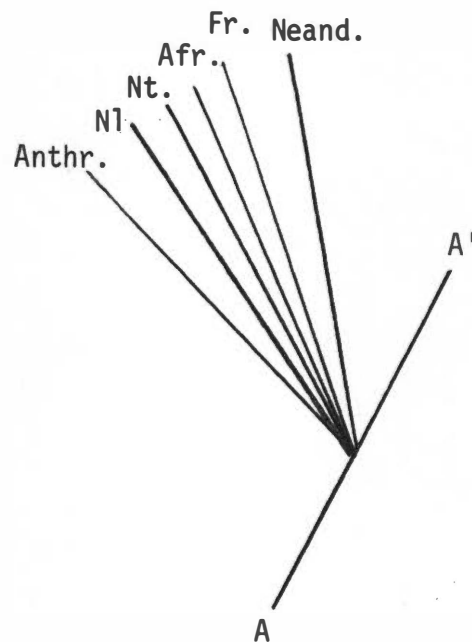


Figure 5. Variations of the axillo-glenoid angle in different groups. The line AA' indicates the direction of the axillary border kept constant (after Vallois 1932:22).

Neand., Neandertal, 145°; Fr., French, 135°; Afr., Blacks of Africa, 131°; Nt., Negrito, 126°; Nl., Negrille, 120°; Anthro., Anthropoids, 108°.

glenoid fossa to be a characteristic of the scapulae from the Shanidar site. Stewart pointed out, however, that although the height/breadth indices of the fossae of Neandertal's are lower than those of modern men, they are not entirely beyond the upper portion of the modern range. They do not, therefore, completely differentiate Neandertals from modern men. The wider axillo-glenoid angle and a broad scapular notch are two other Neandertal features which exhibit differing tendencies from modern man, but again are within the modern hominid range. Stewart (1962a) concluded that the form of the axillary border is the only distinguishing feature between the scapulae of modern men and Neandertals. Both the left and right scapulae of Shanidar I were classified by Stewart as Neandertal types, but Shanidar III has a variant of the Chancelade type.

In 1964 Stewart investigated the contention that the original Neandertal scapula has an unusual backward tilt of the glenoid cavity. Klaatsch (1901) had originally reported this and Schwalbe (1906) had agreed. McCown and Keith (1939), however, believed this unusual inclination to be an extreme variation peculiar to this individual. Vallois (1932) had suggested that the marked inclination of the Dusseldorf scapula was nothing more than an illusion. Stewart (1964) concluded that the degree of dorsal inclination is slightly greater in the Dusseldorf specimen's glenoid cavity than in modern men but that pathological arthritic changes on this specimen probably distorted the measurement. Stewart believes that this individual's left scapula, had it been found, would have been within the range of modern men in dorsal inclination of the cavity. He reasoned that the dorsal inclination of the glenoid cavity is more pronounced on the right side than on the left side because the Neandertal specimen--having suffered

an injury to his left elbow--probably used his right arm excessively which provoked greater arthritic buildup.

In the postcranial studies of the Amud man, Endo and Kimura (1970) also investigated the dorsal inclination of the glenoid cavity. They emphasized that the marked inclination does exist and is not merely an extreme variation of the individual from Dusseldorf. They also noted that Amud I compares with Dusseldorf in the narrowness of the glenoid cavity and has a distinct *sulcus dorso-axillaris*.

Heim (1974) restudied the La Ferrassie remains and remarked on the great enlargement of the glenoid cavity of the La Ferrassie subjects. He also pointed out the unusually high glenoid index, especially on the right scapula. While the index, 68.1, is larger than some of the other Neandertals', it remains within the basic Neandertal range and within the tendency for narrow glenoid cavities. In general, the La Ferrassie subjects were very robust and had strong musculature, especially in thoracic and scapular muscles. According to Heim, these specimens also exhibited deep subspinous and subscapular fossae.

Recently, Trinkaus (in press) speculated on the causes of the differences on the axillary border between Neandertal and modern man. Trinkaus based his functional interpretation of this problem on the theory that Neandertal man's cultural adaptive level would have produced greater biomechanical stress in the shoulder region. It can be seen from the very large deltoid tuberosities on Neandertal humeri that the deltoid muscle was very powerfully employed. Thus, muscles which work in conjunction with the deltoid muscle during abduction to maintain the head of the humerus in the glenoid fossa would have had to exert



greater force. The *teres minor* is one of these resistive muscles, as well as being one of the muscles which laterally rotates the humerus. In this role as lateral rotator, *teres minor* would have had to resist the strong medial rotators in order for precise and powerful adduction to take place. This hypothesis is in partial agreement with a basic theory of this thesis, and will be further discussed in the conclusions. Trinkaus supports his explanation with evidence of the bilateral distribution of morphological types on the axillary border. Greater development of *teres minor*, as seen in Chancelade-type borders, occurs on the right side in 70% of his sample. This point is also explored in this thesis and further elaborated.

Other areas of the scapula have been studied by all of these scholars and certain features which appear repeatedly in Neandertal man should be noted. One of these features is the already mentioned scapular notch on the superior border. Boule (1911/13) noted that the Neandertal scapulae which he observed had large scapular notches, and he considered this to be a Neandertal characteristic. Vallois (1946) agreed with this contention. The specimens at Krapina were found to have large notches, as does Shanidar I (Smith 1976b, Stewart 1962a). McCown and Keith (1939) described Skhul V and Tabun I as having small notches; however, Stewart claims that breakage in both these cases misled those authors and that ". . . it seems unwise, therefore, to conclude that the Mount Carmel scapulae have the lateral part of the superior border shaped differently from that of other Neanderthals" (Stewart 1962a:794).

The coracoid process is a differentiating feature at Mount Carmel

in that Skhul V shows ". . . the markings for the coraco-clavicular ligaments, the trapezoid and the coracoid. . . as in the modern caracoid, quite different from those seen in the same part of the Tabun scapula" (McCown and Keith 1939:138). This process is also peculiar to Tabun I, as the post-glenoid root begins as a thickening on the dorsal lip of the glenoid. McCown and Keith found this to be similar to the fractured coracoid remains of the original Neandertal specimen. Stewart (1962a) called attention to the lack of a well-developed "heel" at the proximal end of the horizontal part of the coracoid of Shanidar I, which is also a feature of Tabun I. This "heel" is seen in Skhul V and in modern men. The portions of eight coracoids found at Krapina, however, seem to be basically modern (Smith 1976a). At Krapina, it must be recalled, the stratigraphic levels and hence the dates of the various scapulae is still uncertain.

#### *General Scapular Studies*

Most other anthropological studies on the scapula have often been primarily concerned with studying the proportions of the bone to establish racial and sexual differences. Few have been concerned with the morphology of the axillary border. These studies will be briefly mentioned here.

In their study of the scapula, Bainbridge and Genoves (1956) discuss, among other things, the axillary border with regard to differences between the sexes. They disagree with Vallois (1932) concerning the median axillary crest. Whereas Vallois said this crest is more distinct in females than males, Bainbridge and Genoves find it is sometimes poorly developed in females and well marked in

males. Occasionally a pronounced dorso-axillary crest replaces it. They found a 65 year old male who looked much like the Neandertal type due to a strongly developed dorso-axillary crest (which transgressed the infraspinous fossa) and a very light ventro-axillary crest which disappeared below the middle one-third of the border. They also found that a laterally directed ventral gutter is more commonly found in male bones, especially on the bones of robust individuals. They considered this characteristic as one of the better methods of determining sex from the scapula, when used by an experienced observer.

Finally, a scoring system was derived by Bainbridge and Genoves for use in sexing scapulae. This involved measurements of length, breadth, axillary border width, glenoid cavity length and width, and length of axillary border.

In a study of the shoulder girdle of the Australian aborigine, van Dongen (1963) reported that the dorsally inclining lower part of the axillary border, which increases the area of origin for the subscapularis muscle, is more pronounced in male bones. Contrary to Bainbridge and Genoves, who suggested this characteristic as a guide to sex, van Dongen stated that it is merely an expression of muscular development. (One could point out that greater muscular development usually occurs in male bones.) Van Dongen quantified this dorsal inclination as to sex: 18% of males and 50% of females had a small extent of dorsal inclination area; 33% of males and 30% of females were moderate; 49% of males and 20% of females had extensive areas of dorsal inclination.

Van Dongen's study involved 216 humeri, 134 scapulae, and 103

claviculae of Australian aborigines. In general, he found that the shoulder girdle and humerus of aborigines fall within the normal range of human variation. However, the scapulae in Australians of both sexes tend to be shorter and narrower than in most other groups. Functional responses of the bone were held by him to be responsible for these differences.

Graves (1921) was interested in the contour of the vertebral border and quantified three types (concave, straight, and convex) in his study group of this area in various populations. He attempted to correlate the various types of vertebral borders with other features of the scapula. He found that the "straight" and "concave" contoured scapulae had much in common and classified them as "scaphoid." These make up a large percentage in earlier and contemporary groups; although in ancient Egyptians the convex is the predominating type. He concluded that all three types are found in all ancient and modern groups and were probably primeval with man.

In a further study, Graves (1939) concluded that these various forms are determined by intrinsic genetic factors and that the scaphoid type is indicative of a very weak constitution of the individual. Wolffson (1950) disputed this contention after performing experimental studies on rats' vertebral border muscles. She concluded that function, not heredity, greatly affects the shape of the vertebral border.

Hrdlička (1942a,b,c) contributed a large, thorough series of studies of the scapula to the literature. In discussing the various shapes of the body of the scapula he remarked that the types, to some degree, reflect the varying development of the vertebral border which

is "... doubtless largely of functional causation; but to some extent they also occur genetically in bones of various dimensions, and to that extent fall within the scope of human heredity and typogeny" (1942a:76). Hrdlička disagreed with Graves' attempt to connect the concave type with pathology or constitution, saying that this would only apply to conditions that produced a weakening of the muscles attached to the bone during childhood and continued throughout the growing period. Hrdlička believed that a tendency to a particular form is inherited with "... the result subject to functional modification" (1942a:77), as in all other bones of the skeleton. Thus the forms are partly determined phylogenetically, and partly acquired ontogenetically.

Forms of the various borders, side differences, racial and sex differences were studied in Whites, North American Indians, Eskimos and American Negroes in these 1942 studies by Hrdlička. Hrdlička's works mainly confirmed the data of Vallois with regard to the reality of the existence of racial characteristics of the scapula.

Gray (1941) determined the frequencies of certain features not discussed in normal accounts on the scapula or those which deviate from descriptions in most anatomy texts. Some of these are: a sulcus for the circumflex scapular artery, anomalous scapular foramina, muscular cristae, shape of glenoid fossae, and shape of the acromial process. He concluded that genetic factors play the major role in producing certain variations, but that their manifestation may occasionally be influenced by special functional factors.

*Functional Studies of the Shoulder Girdle*

Roentgenographic studies of movement in living subjects offer helpful insights into muscular relationships and function during various types of movements. Inman, Saunders and Abbott (1944) examined the shoulder functional mechanism from several aspects. In comparing various forms with regard to the progression toward freeing of the forelimb, they explored various characteristic skeletal changes. The major focus of this study was the radiological analysis during elevation of the arm in living subjects. Their purpose was to note relative use of various muscles and relative movement of the various bones of the shoulder area. They noted that ". . . striking alterations in the muscles, in respect to both their size and points of attachment, . . . suggest that the functional demands of the extremity, expressing themselves through the action of the muscles, have caused the skeletal changes" (Inman et al. 1944:4).

While Inman et al. had conducted their studies of abduction in the coronal and frontal planes, Freedman and Munro (1966) studied the complex varieties of movements during abduction of the arm in the scapular plane. This study was also conducted roentgenographically using living subjects. Relative amounts of scapular and glenohumeral movements were calculated in each subject during this procedure.

Oxnard has authored or coauthored a number of studies on primate scapulae or shoulder girdles, usually with regard to locomotor function. In an effort to extract a picture of functional adaptation of the shoulder region he chooses characters or dimensions for his morphometric studies which show both locomotor and taxonomic correlation. While these

studies rarely offer information directly relevant to the problem of this thesis, they do offer insight into methods of study and some effects of function on the morphology of the bone itself. Once it is realized that certain features of the shoulder girdle are mainly functionally adaptive, one can use these morphometric features and consider functional mechanisms with regard to related muscular masses (Oxnard 1967). For example, one study involved comparing the shoulder girdles of brachiators and quadrupeds. Results indicated that in brachiators the glenoid cavity is directed more cranially and the clavicle is longer, with its lateral end twisted more cranially than in the quadruped. It is thought that these differences may be associated with freer mobility of the raised arm in brachiators (Ashton and Oxnard 1964). Other features of muscular insertion can show that the mechanisms for rotating the scapula as the arm is raised is more effective in brachiators than in quadrupeds.

## CHAPTER II

### MATERIALS AND METHODS

#### I. MATERIALS

The remains of 95 female and 116 male Arikara American Indians from the Larson, Leavenworth, Mobridge and Rygh sites of South Dakota comprise the comparative sample used for this study. These sites are all within a few miles of each other along the Missouri River in South Dakota (Bass n.d.). The occupations are from both pre- and proto-historic times. All comparative material is housed in the Osteology Lab of the Anthropology Department of the University of Tennessee, Knoxville, and has been studied by the author with the kind permission of Dr. William M. Bass. Information concerning the Neandertal material was taken from the literature, which has been discussed in Chapter I.

#### II. METHODS

Age and sex for each of the individuals in the comparative collection was determined from previous studies and records at the University of Tennessee. The study material was then divided into groups according to age and sex. Females were separated from males for the statistical studies and each sex grouping contained three age categories: 18-30 years of age; 30-40 years of age; and 40 years of age or older. This procedure served to facilitate comparisons and observations concerning the premise that morphology is a function of age and muscular exertion.



The morphology of the axillary border of the scapula, the major focus of interest here, was carefully noted for each scapula used in this study. The morphology of the axillary border, which is very variable, was classified into five categories.

1. Type 1: an axillary border with a clear ventral sulcus, oriented ventrally. This is considered the "normal" type for modern *Homo sapiens* (Figure 1, p. 8).
2. Type 2: axillary borders where a ventral groove is oriented laterally rather than ventrally (considered an intermediate type by von Eickstedt 1925), or a border with an incipient double groove. It appears that a crest is forming on the cranial one-third of the border, which if continued, would divide the border into two sulci. In this case, however, the crest normally appears to be closer to the dorsal aspect. In this type, the entire border is oriented ventrally and the ventral groove is the larger of the two grooves (Figure 6, left, is an illustration of this type).
3. Type 3: a border divided more or less in the center, but the orientation is more ventral than lateral.
4. Type 4: the Chancelade type. A clear crest divides the laterally oriented axillary border into two grooves, the ventral groove being slightly larger than the dorsal, usually (see Figure 1A, p. 8; Figure 4, p. 17; and Figure 7).
5. Type 5: a bisulcate border (Chancelade type) but the dorsal groove faces slightly dorsally. This type will be referred to as a special or Type 5 (Figure 6, Figure 8, Figure 9). In several of the cases exhibiting this morphology,



Figure 6. The scapulae of a male Arikara Indian specimen with a Type 2 variant on the left (laterally oriented ventral sulcus) and a Type 5 or special morphology on the right. This specimen was in the over-40 age group. Note the ruggedness of the infraglenoid tubercles, especially on the right.



Figure 7. Left scapula of an Arikara Indian male, in the over-40 age category. This scapula further demonstrates the variability of morphology on the axillary border. The border is classified as the Chancelade type, but is narrower in the central portion of the border than other males with this morphology.



Figure 8. The procedure used for measurement of the axillo-glenoid angle using an industrial goniometer. Note the transgression by the axillary groove on to the dorsal surface of the scapulae. The situation in these scapulae bear some resemblance to the situation on the La Ferrassie I scapulae seen in Figure 1, page 8.



Figure 9. Another example of variability on the axillary border of the scapula. This over-40 male Arikara Indian exhibits a variant of the Chancelade morphology on the left, and an extreme variant of this morphology on the right (Type 5, special). Here the teres minor muscle insertion seems to encroach to some degree on the dorsal aspect of the scapula.

the dorsal groove appeared to be slightly larger than the ventral, as well as being dorsally oriented (Figure 3, p. 13, is an illustration of this case).

6. Type 6: the Neandertal type; a dorsal groove, dorsally oriented.

The maximum width of each axillary border was measured. This measurement was helpful in determining handedness, as the right border is usually wider than the left in right-handed persons (Hrdlička 1942a).

The length and width of the glenoid fossae were measured and the length/breadth indices computed (Martin 1928, Nos. 12, 13). Neandertals have a tendency toward narrower fossae (thus lower indices) than modern men (Vallois 1932, Stewart 1962a). Consequently, an attempt was made to see if narrower fossae correlated significantly with particular types of axillary border morphologies. Neandertals also normally exhibit shallower fossae than modern men (Stewart 1962a). The depth of the fossae were evaluated by the investigator and placed into categories such as shallow, moderate depth, and deep. An effort was then made to find correlations between fossa depth and axillary border type.

Robusticity of the infraglenoid tubercle is often an indication of general usage or muscularity in the shoulder area. A scale of robusticity was constructed and subjective evaluations noted. As Neandertals had very robust infraglenoid tubercles (McCown and Keith 1939), positive relationships were expected between robust infraglenoid tubercles and Chancelade and other non-ventral types.

The orientation of the glenoid cavity is measured by the angle

formed between the axillary border and the long axis of the glenoid cavity. This was accomplished with an industrial goniometer (Figure 8). Stewart's method (1964) was utilized here in accord with Martin (1928: Martin No. 17). Stewart pointed out that he was able to obtain accurate measurements of this angle by measuring directly on the bone rather than using the more complicated method used by Vallois (1932). This measurement was considered relevant as there is a tendency among Neandertals toward having more laterally oriented glenoid fossae than that which is found in anatomically modern man. Thus, it was expected that higher axillo-glenoid angles would correlate positively with Chancelade and related morphologies.

Two measurements were taken on the humerus that seemed relevant to the relationships found in the shoulder area. As Neandertals often had humeral heads which measured greater transversally than vertically (McCown and Keith 1939), these measurements were taken and humeral head indices were calculated. The transverse measurement was determined by placing the sliding calipers horizontally on the humeral head and finding the maximum distance from rim to rim of this hemisphere. The caliper points were placed at the most proximal tip and the most distal tip of the rim in order to find the vertical measurement (Martin 1928, Nos. 9,10).

Since it was reported in several studies of Neandertals (particularly by McCown and Keith 1939) that Neandertal humeral heads are more cranially directed than those of modern men, the angle of the humeral head to the diaphyseal axis was sought out. A device was used that employed an osteometric board. The humerus was placed on the board

with the anterior side facing downward (Martin 1928:No. 17). In this position, the humeral head was seen in profile. A thread was drawn paralleling the axis of the head in profile, following a point on the most proximally seen portion of the rim to a point on the most distally seen portion of the rim. Another thread was drawn down the axis of the shaft. At the point where these two lines intersected, a protractor measured the angle between the two lines.

In order to determine handedness (Hrdlička 1932), it was noted whether the left or right humerus was longer, and muscularity of the two shafts was compared. When the right humerus seemed more muscular, it was assumed that the individual used that arm more and was right-handed.

Most of the computations were achieved with the aid of the facilities of the IBM 360 computer at the Computer Center, University of Tennessee, Knoxville. Indices were determined by hand calculation. The CONDESCRIPTIVE program of the Statistical Package for the Social Sciences (SPSS 6--Nie et al. 1975) was employed in order to find the mean, range, skewness and kurtosis for the continuous variables. The computer was also employed to find frequencies of the various morphological border types for the various age and sex groupings. After the RECODE procedure was employed to group continuous variables into high and low groups around each of the respective means, the CROSSTABS program was employed to find relationships. Crosstabulated tables were given between the various morphological groups on the axillary border and other relevant variables.



## CHAPTER III

### RESULTS AND DISCUSSION

The results of this investigation may be divided into two groups: (1) results involving the morphologies on the axillary border alone and the incidence of various types in each sex, on each side, in each age group; and (2) results of the crosstabulation tables which showed the relationships between various morphological variables.

The results of the findings on the axillary borders of 211 Arikara American Indians can be seen in Table II. These results will be discussed first.

Among females, one sees fewer Type 1 scapulae on the left side with increasing age. Approximately 73.0% of the 18-30 year old group exhibits the ventral type, while 48.0% exhibits a ventral type in the 30-40 year old group. Only 36.0% in the over-40 age group possesses a ventral type. Males exhibit similar percentages throughout the age groups on the left side: 49.0% in the 18-30 age group, 52.0% in the 30-40 age group, and 46.0% in the over-40 age group. On the right side, the females again show a decrease with age in the percentage of ventral morphologies. They have an incidence of 60.0% ventral types in 18-30 year olds, 40.0% in 30-40 year olds, and 28.0% in the oldest group (over 40). Males exhibit their highest percentage of ventral types on the right side in the youngest group (38.0%), with fewer ventral types appearing in the next age group (25.0%), but a slight increase again of the incidence of this type in the oldest group (33.0%). Thus, particularly in the females, where one sees a definite consistent decline

TABLE II  
MORPHOLOGICAL CATEGORIES FOR ARIKARA INDIANS BY AGE AND SEX

Age	Sex	Ventral		Types 2 and 3		Chancelade Type		Type 5--Special	
		Left	Right	Left	Right	Left	Right	Left	Right
18-30	F	29(72.5%)	23(60.5%)	10(25.0%)	9(23.5%)	1( 2.5%)	6(16.0%)	0	0
18-30	M	21(49.0%)	17(38.0%)	16(37.0%)	13(29.0%)	5(11.6%)	14(31.0%)	1(2.3%)	1(2.0%)
30-40	F	19(50.0%)	16(41.0%)	13(34.0%)	11(28.0%)	6(16.0%)	11(28.0%)	0	1(3.0%)
30-40	M	27(52.0%)	14(29.0%)	13(25.0%)	22(46.0%)	12(23.0%)	12(25.0%)	0	0
40+	F	5(36.0%)	4(28.0%)	8(56.6%)	6(42.6%)	1( 7.0%)	4(28.6%)	0	0
40+	M	6(46.0%)	4(33.0%)	3(23.0%)	2(17.0%)	4(31.0%)	4(33.0%)	0	2(17.0%)

Note: Numbers outside of parentheses signify numbers of specimens.

of the incidence of ventral types with age, it appears that morphologies of other than the ventral (modern) type may be a function of use in the shoulder area.

The next two morphological categories, Type 2 and Type 3, appear to be somewhat related to the Chancelade morphology. The results for these two previously described types have been grouped together for discussion. Females of these categories exhibit the smallest percentage (25.0%) of the types on the left in the youngest group with some increase shown (33.0%) in the second age group. A considerable increase in the incidence of these types is seen in the oldest group of females on this side. These morphologies show a slight decrease in incidence with age among the males on the left side: 37.0% in 18-30 year olds, 23.0% in 30-40 year olds, and 23.0% in the over-40 group. On the right side, females again show an increase in the incidence of these types with age, ranging from 23.5% in the youngest group to 42.6% in the oldest group. Percentages of these types in males jump from 29.0% in the youngest group to 46.0% in the second age group, but only 17.0% in the oldest group have these types.

The Chancelade type of border is seen in only 2.5% of the young females on the left side and 11.6% of males of this age group on the left side. If one postulates that this type is at least partially a function of muscular stress or use, it is not surprising that few young scapulae exhibit this morphology. The Chancelade type increases to 15.0% in 30-40 year old females on the left side. The males show an increase of the Chancelade type with age on the left side: from 11.0% in the 18-30 year olds, to 21.0% in the 30-40 year olds and 23.0% in

the over-40 group. On the right side, where greatest use of the arms is expected in a predominantly right-handed population, females show an increase in percentages of the Chancelade type with age (15.0% to 28.0% to 27.0%). Males do not exhibit a clear pattern of change on this side, having 27.0% in the youngest age group, 22.0% in the next age group, and 30.0% in the oldest group.

Type 5, found very rarely in this sample, is basically an extreme variant of the Chancelade type, where the dorsal sulcus is more extensive or more dorsally oriented than in the normal Chancelade morphology. This special type is found in approximately 2.0% (one scapula each side) of the youngest male group on both sides. Females have an incidence of 3.0% (found on one scapula) in the 30-40 year old group on the right side. Two scapulae, or 17.0% of the over-40 male scapulae on the right side exhibited this special morphology. Not one of the modern specimens examined exhibited a true Neandertal type border.

In overall comparison between left and right sides, a greater percentage of the ventral type is found on the left side within each age group. This seems to support the hypothesis that the ventral type is indicative of less muscular stress or use in the shoulder region, as the left arm is used less in right-handed persons.

Of the next two morphological types, where there are indications of incipient Chancelade morphology or a laterally oriented ventral groove or a ventrally oriented bisulcate (double groove) border, the percentages are slightly higher on the left side, except in males of 30-40 years of age. There 23.0% have Types 2 and 3 on the left and 46.0% have

them on the right side. Von Eickstedt (1925) believed that a laterally oriented ventral groove (Type 2) is somewhat equivalent to the Chancelade type in that it is an "in-between" step between the Neandertal type and the modern type. In the Arikara sample, indications are that advancing age generally correlates with an increase in incidence of these types, but there is not always predominance on the right side.

In the Chancelade category, however, the incidence is almost always much greater on the right. Not only is there a generally greater incidence of Chancelade types on the right side (and conversely a greater incidence of ventrals on the left); but there are also generally greater frequencies of the Chancelade and related types with advancing age and a concurrently general decrease with age of ventral morphologies.

In Arikara females of advancing age, one sees indications of greater muscular development on the bones. This is to be expected as the adult females of the Arikara Indians performed many difficult tasks such as hoeing with buffalo scapulae. It is said that they were often treated as slaves and were expected to perform many of the life-supportive tasks in their daily life (Abel 1939). Thus, by age 30-40, one would not expect to find a significant difference between males and females in the incidence of morphological types which are indicative of greater use or muscular stress. The results on the right side in the Chancelade category, therefore, are nearly equal for males and females in both the 30-40 age group and the over-40 age group.

Other morphological classifications were divided into discrete categories for the purpose of seeking out related factors by means of computer analysis. Many of these factors are necessarily more

subjectively evaluated than the axillary border morphologies. Each specimen was judged and classified with regard to infraglenoid tubercle robusticity, glenoid fossa depth, and general muscularity of the scapula. It was expected that the more muscular scapulae would correlate well with the Chancelade or other non-ventral types. These categories for scapular muscularity were: (1) very muscular; (2) moderately muscled; (3) slightly to moderately muscled; and (4) slightly muscled.

Of Arikara females in the 18-30 age group with Chancelade patterned borders, 33.0% had very muscular scapulae and 33.0% were moderately muscled. The next age group of females (30-40) showed an increase of very muscular scapulae correlated with Chancelade borders (40.0%). Of the moderately muscled scapulae, 40.0% had Chancelade borders. However 9 of 12 ventrally grooved scapulae were also very muscular, as was the single specimen with the special morphology. All of the females over 40 with Chancelade configurations on the axillary border had very muscular scapulae. Those with Type 3 (ventrally oriented bisulcate) had an incidence of 50.0% very muscular and 50.0% moderately muscular.

Among males, those of 18-30 years of age with the Chancelade pattern on the axillary border had an incidence of 58.0% of very muscular scapulae. The single scapula with the special morphology in this age group was also very muscular. The next age group (30-40) found 60.0% of those with the Chancelade type to have moderately muscular scapulae, and 40.0% to be very muscular. Of those scapulae with the lateral ventral type, incipient bisulcate, or ventral bisulcate

(Types 2 and 3) configurations, a total of 71.0% were in the very muscular category. Well muscled scapulae were also associated with the Chancelade pattern in the oldest males. Of the two scapulae in this group with the special morphology, one had a very muscled scapula and one was moderately muscled. The two ventral types in this age group (over 40), however, were also very muscular, as were a large percentage of ventral types in the 30-40 year old group. There appears to be somewhat of a relationship between the Chancelade pattern and other non-ventral patterns on the axillary border and general musculature. It is possible that the investigator's judgment may have been distorted by the male-female differential. This may be reflected in the frequencies seen among the females.

Categories of robusticity of tubercles were: (1) very well developed; (2) well developed; and (3) moderately developed. A correlation between well developed tubercles and Chancelade borders was expected, as Neandertals generally had very well developed tubercles.

In the youngest Arikara females the Chancelade type borders were correlated positively with 40.0% of scapulae with well developed tubercles and 40.0% of those with moderately developed tubercles. Among the specimens with ventral borders only 20.0% had well developed tubercles and 60.0%, moderately developed tubercles. Those with Type 2 morphologies were all moderately developed.

In the next age group of females (30-40 years old), only 14.0% of those with Chancelade borders had well developed tubercles and 86.0% were moderately developed. In this group, 80.0% of the ventral scapulae had well developed tubercles; thus it appears that there is

not a good fit between Chancelade morphology and well developed tubercles in this group. However, both Chancelade specimens of the oldest females had well developed tubercles.

Among the males there is a better fit or meeting of expectations. Of the youngest males with Chancelade borders, 56.0% had well developed tubercles. The single specimen with the special morphology (Type 5) had a very well developed tubercle as did a specimen with Type 3 morphology. Two other (33.0%) specimens with Type 3 morphology had well developed tubercles and three had moderately developed tubercles. Among 30-40 year old males, 85.0% of those with Chancelade type borders had well developed tubercles as did 100.0% (8) of those with Type 3 borders. The single specimen with the special morphology (Type 5) among the oldest males had a very well developed tubercle, as well as 75.0% of those of this group with the Chancelade pattern.

Thus the males seem to confirm the proposed hypothesis that scapulae with Chancelade and other non-ventral type borders would generally have well developed tubercles. The females, however, generally do not seem to conform to this pattern. It may be that the subjective judgment of the investigator was again influenced by the differential between male and female. The handling of male and female scapulae sequentially may have distorted judgment with regard to the tubercles, as tubercles of female scapulae may be relatively less well expressed.

As Neandertals generally had rather shallow glenoid fossae, the study endeavored to establish whether this factor is in any way allied with border morphologies in modern hominids. Fossa depth categories



were established as: (1) deep fossae; (2) moderately deep fossae; (3) shallow-moderately deep fossae; and (4) shallow fossae.

The greatest number of fossae were of moderate depth in the entire population, with very few individuals having either deep or shallow fossae. Young Arikara females had a 60.0% incidence of moderately deep fossae; 20.0% were shallow and 20.0% were shallow-moderate in the group with Chancelade-type borders. Those with Type 3 borders had an incidence of 60.0% moderately deep, and 40.0% shallow. The percentages among scapulae with ventral borders were similar to those with Chancelade-type borders.

Young males with the Chancelade pattern had a 55.6% incidence of moderately deep fossae and 44.4% had shallow-moderately deep fossae. Two specimens (25.0%) of the ventral scapulae had shallow fossae--an unexpected result. One specimen of the ventral group had a deep fossa, the remainder were of moderate depth.

Females 30 to 40 years old with Chancelade-type borders exhibited an incidence of 62.5% of moderately deep fossae, 25.0% incidence of shallow-moderately deep fossae, and 12.5% of shallow fossae. None of the ventral scapulae had shallow fossae, although one specimen had a deep fossa. None were found to be deep of the scapulae with Chancelade-type borders. The males of this age had an 11.0% incidence of shallow, and 44.0% incidence of shallow-moderately deep fossae associated with Chancelade morphology. None of these had deep fossae. Those specimens with ventral patterns were moderately deep in 75.0% of the cases. These were expected frequencies which support the hypothesis.

In the oldest group of females (over-40), one half had shallow

fossae where Chancelade-type borders were present. The single ventral scapula of this age group was moderately deep. Among males with Chancelade-type borders 25.0% were shallow-moderately deep and 75.0% were moderately deep. In this group, where 10 fossae were seen, there was some difficulty in judging fossa depth due to arthritic buildup of the fossa margins.

The evidence gathered here yields inconclusive results with regard to the correlation between fossa depth and particular types of border morphology.

Other aspects of the scapula and humerus were studied using angles and indices. These are in the category of continuous variables. The length/breadth index of each glenoid fossa was computed and the mean and range was found for this variable by the computer. As previously mentioned, Neandertals had relatively narrower glenoid fossae than modern men (Stewart 1962a, Vallois 1932). Thus the fossa indices were subsequently recoded into two discrete groups and crosstabulation tables between border morphologies and fossa index groupings were derived so that the investigator could assess whether Chancelade morphologies correlated with the low or high index group. The index groups were: (1) low index group, where length/breadth indices ranged from the lowest through 72.5; and (2) a high index group, where indices were above 72.5.

In the youngest group (18-30) of Arikara females, those with Chancelade-type borders had low indices in 50.0% of the cases. Of those with ventral borders, 57.0% had high indices, which is more commonly found in modern groups. Type 2, the lateral ventral or

incipient bisulcate morphologies, had a 60.0% incidence of low fossa indices. In the next age group (30-40) only 36.0% of those with Chancelade morphologies had low indices. This did not meet expectations. However, Type 3, ventrally oriented bisulcate borders, correlated well with low indices, having a 75.0% incidence. Additionally, the group with ventral morphologies met the expectations postulated here as this group had 64.0% in the high index group. The oldest group (over-40) of females was a very small sampling (11), thus results may not be reliable. The two specimens in the group with ventral grooves had wide fossae as expected; however, only one (25.0%) of the four with the Chancelade pattern had a low index. The single Type 3 specimen also had a very low index, which meets expectations. The over-40 females, as a group, had a high proportion of high indices (73.0%).

Among young Arikara males (18-30), those with Chancelade-type borders had five specimens in each of the index groups--a 50-50 split between low and high indices. Males of 30-40 years of age had only three (30.0%) with Chancelade-type borders that had low indices, an unexpected result. Generally, the findings in the oldest group of males were contrary to expectations among the specimens with the Chancelade morphology; and other types had half in the low index, half in the high index group. It appears, from these results, that the low fossa index is not necessarily correlated with Chancelade and related morphologies. The tendency among Neandertals toward having narrower fossae may not have a relationship with the morphology of the axillary border *per se* and may have been influenced by other factors.

The axillo-glenoid angle of Neandertals ranges from  $139^{\circ}$  to  $146^{\circ}$ , which is at the extreme high end of the range for modern men (Vallois 1932). The mean for this variable in the Arikara was found to be  $130^{\circ}$ . Thus in recoding the values into high and low groups, the low group included those with angles under  $130^{\circ}$  and the high group had angles of  $130^{\circ}$  and above.

In general, the Arikara population had more specimens falling in the low group, even though the mean was close to  $130^{\circ}$  for each of the major sex and age groupings. Vallois (1932) said that generally low values were found in most non-technologically advanced societies. The Arikara may be considered in this category. In the comparative sample of Arikara scapulae, the expected correlations between high axillo-glenoid angles and Chancelade-type morphologies were generally not found (Table III).

In the youngest females (18-30), all six of those with Chancelade-type borders had angles under  $130^{\circ}$ . However, specimens with ventral morphologies also had a high percentage of low angles (81.0%).

The speculation that Chancelade and related morphologies would correlate well with scapulae with high axillo-glenoid angles was met somewhat in the over-40 group of females. Although this group was split 50-50 in the general population with regard to high and low angles, the specimens with ventrally oriented bisulcate borders (Type 3) had a large incidence (67.0%) of high angles. The single ventral specimen had a low angle.

The youngest males (18-30) also had an equal number in the low and high groups of those with the Chancelade pattern on the border.

TABLE III  
AXILLO-GLENOID ANGLES CORRELATED WITH AXILLARY  
BORDER MORPHOLOGIES--RIGHT SIDE

Age	Sex	Morphologies	Low Angles	High Angles
18-30	F	Ventral	17( 81.0%)	4( 19.0%)
		Type 2	3( 60.0%)	2( 40.0%)
		Type 3	1( 50.0%)	1( 50.0%)
		Chancelade	6(100.0%)	0
18-30	M	Ventral	3( 37.0%)	5( 62.0%)
		Type 2	2( 67.0%)	1( 33.0%)
		Type 3	3( 43.0%)	4( 57.0%)
		Chancelade	6( 50.0%)	6( 50.0%)
30-40	F	Ventral	8( 57.0%)	6( 43.0%)
		Type 2	5(100.0%)	0
		Type 3	4(100.0%)	0
		Chancelade	10( 91.0%)	1( 9.0%)
30-40	M	Ventral	7( 70.0%)	3( 30.0%)
		Type 2	5( 83.0%)	1( 17.0%)
		Type 3	6( 46.0%)	7( 54.0%)
		Chancelade	6( 67.0%)	3( 33.0%)
40+	F	Ventral	1(100.0%)	0
		Type 2	1(100.0%)	0
		Type 3	1( 33.0%)	2( 67.0%)
		Chancelade	2( 50.0%)	2( 50.0%)
40+	M	Ventral	1( 33.0%)	2( 67.0%)
		Type 2	1( 50.0%)	1( 50.0%)
		Type 3	0	0
		Chancelade	3( 75.0%)	1( 25.0%)

Note: Figures outside of parentheses signify number of specimens.

Additionally, the 30-40 year old males had six or 67.0% with low angles. The specimens with ventral borders showed a 70.0% incidence in the low angled group, which was among the expectations. This group of females, in general, however, had a greater frequency of low angles. As previously stated, the low angle seems to be a characteristic of contemporary, non-technologically advanced societies as the high angle was of Neandertals. Perhaps the value of the axillo-glenoid angle is racially determined in both Neandertals and modern groups and is independent of function or border morphology. It should be noted that, while the high axillo-glenoid angle is a tendency among Neandertals, it is not without exception, notably in the Tabun I specimen. This specimen has the Neandertal (dorsal) groove, but the axillo-glenoid angle is only  $132^\circ$ , within the modern range. Tabun is the only positively established female in the Neandertal scapular group, which may have some bearing on the situation.

Humeral head indices were recoded into two groupings: (1) those with indices from the lowest to 93.0; and (2) those with indices of 93.1 and higher. The high group is considered closer to Neandertal types, as Neandertals often had indices of 100 or more. These high indices were due to the fact that the transverse measurement of the humeral head was greater than the vertical measurement (McCown and Keith 1939). Thus it was expected that high humeral head indices would correlate well with Chancelade-type and related morphologies (Table IV).

In testing the correlation between humeral head index and border morphologies, results for the youngest Arikara female do not meet hypothesized expectation. However, the youngest male (18-30) Arikara

TABLE -IV  
HUMERAL HEAD INDICES CORRELATED WITH AXILLARY  
BORDER MORPHOLOGIES--RIGHT SIDE

Age	Sex	Morphologies	Low Indices	High Indices
18-30	F	Ventral	6( 37.5%)	10( 62.5%)
		Type 2	0	2(100.0%)
		Type 3	2( 67.0%)	1( 33.0%)
		Chancelade	4( 80.0%)	1( 20.0%)
18-30	M	Ventral	5( 62.5%)	3( 37.5%)
		Type 2	1( 50.0%)	1( 50.0%)
		Type 3	3( 50.0%)	3( 50.0%)
		Chancelade	3( 33.0%)	6( 67.0%)
		Special	0	1(100.0%)
30-40	F	Ventral	7( 50.0%)	7( 50.0%)
		Type 2	4( 80.0%)	1( 20.0%)
		Type 3	3( 60.0%)	2( 40.0%)
		Chancelade	5( 45.5%)	6( 54.5%)
		Special	0	1(100.0%)
30-40	M	Ventral	5( 45.5%)	6( 54.5%)
		Type 2	5( 71.0%)	2( 29.0%)
		Type 3	7( 50.0%)	7( 50.0%)
		Chancelade	2( 22.0%)	7( 78.0%)
40+	F	Ventral	1( 50.0%)	1( 50.0%)
		Type 2	1( 50.0%)	1( 50.0%)
		Chancelade	1( 33.0%)	2( 67.0%)
40+	M	Ventral	1( 33.0%)	2( 67.0%)
		Type 2	0	1(100.0%)
		Chancelade	1( 33.0%)	2( 67.0%)
		Special	1( 50.0%)	1( 50.0%)

Note: Figures outside of parentheses signify number of specimens.

have twice as many specimens with Chancelade-type borders which have high indices of the humeral head as those which have low indices. Conversely, the scapular specimens with ventral borders correlate with 63.0% of humeri having low indices.

Male and female 30-40 year olds meet the expectation that a high correlation will be found between specimens with Chancelade and related type borders and high humeral head indices. Although the indices in the general population of this age group were nearly evenly divided between low and high indices, the specimens with Chancelade borders among females had a 55.0% incidence of high indices. The single specimen with special morphology (Type 5) had a 95 index on both its humeral heads. Of the males of this age with Chancelade-type morphologies, 78.0% had high humeral head indices.

The oldest group of Arikara Indians (over-40) also had high humeral head indices correlated with Chancelade borders. Both males and females had a 67.0% incidence of high indices when Chancelade-type borders were present. Other morphologies showed a generally even division between low and high indices, except for the ventral group in the males, where 67.0% had high indices.

The final variable that was recoded was the angle found between the humeral head and the axis of the shaft. The Neandertal humeral head was usually directed more cranially than is generally seen in modern men ( $35^{\circ}$ - $45^{\circ}$ ), attaining angles of  $53^{\circ}$  and  $54^{\circ}$  (McCown and Keith 1939). The mean for the comparative specimens in this study was approximately  $46^{\circ}$ . The first grouping here included the lowest angled humeral heads up to those with  $46^{\circ}$ , and the second group included those with angles of  $46^{\circ}$  or more (Table V).



TABLE V  
HUMERAL HEAD/SHAFT ANGLES CORRELATED WITH MORPHOLOGIES  
OF THE AXILLARY BORDER

Age	Sex	Morphologies	Low Angles	High Angles
18-30	F	Ventral	5 ( 31.0%)	11 ( 69.0%)
		Type 2	0	2 (100.0%)
		Type 3	0	3 (100.0%)
		Chancelade	0	5 (100.0%)
18-30	M	Ventral	2 ( 28.6%)	5 ( 71.4%)
		Type 2	1 ( 50.0%)	1 ( 50.0%)
		Type 3	1 ( 16.7%)	5 ( 83.0%)
		Chancelade	5 ( 50.0%)	5 ( 50.0%)
		Special	1 (100.0%)	0
30-40	F	Ventral	4 ( 25.0%)	12 ( 75.0%)
		Type 2	2 ( 40.0%)	3 ( 60.0%)
		Type 3	1 ( 20.0%)	4 ( 80.0%)
		Chancelade	3 ( 27.0%)	8 ( 73.0%)
		Special	1 (100.0%)	0
30-40	M	Ventral	5 ( 45.5%)	6 ( 54.5%)
		Type 2	6 ( 86.0%)	1 ( 14.0%)
		Type 3	6 ( 46.0%)	7 ( 54.0%)
		Chancelade	4 ( 44.0%)	5 ( 56.0%)
40+	F	Ventral	0	2 (100.0%)
		Type 2	1 ( 50.0%)	1 ( 50.0%)
		Type 3	0	1 (100.0%)
		Chancelade	1 ( 25.0%)	3 ( 75.0%)
40+	M	Ventral	0	3 (100.0%)
		Type 2	1 (100.0%)	0
		Type 3	0	0
		Chancelade	2 ( 50.0%)	2 ( 50.0%)
		Special	1 ( 50.0%)	1 ( 50.0%)

Note: Figures outside of parentheses signify number of specimens.

In the youngest Arikara females (18-30), all five of the specimens with Chancelade-type borders had high head/shaft angles on the associated humeri. This supports the theory proposed in this work that the Chancelade and related border morphologies will have humeri with high head/shaft angles. The youngest males had equal numbers in the high and low groups where Chancelade borders were present, and 83.0% of specimens with Type 3 (ventrally oriented bisulcate) had high angles. In the 30-40 year old group, females with Chancelade-type borders had a very high incidence (73.0%) of humeri with high angle values. The males of this age group with Chancelade-type borders had a 56.0% incidence in the high angled group. Disturbingly, a nearly equal number of ventrals also correlated with high humeral head angles.

The oldest females had an incidence of 75.0% in the high angled group where the pattern was Chancelade on the axillary border, but the males of this type had a 50-50 distribution between low and high angles of the humeral head.

Thus, there seems to be some correlation between scapulae with Chancelade and related morphologies, and a high humeral head/shaft angle; however, it is not an entirely positive correlation throughout the comparative sample.

## CHAPTER IV

### CONCLUSIONS AND SUMMARY

#### I. CONCLUSIONS

The results of the morphological and metrical investigations suggest that there is an increase with age in the incidence of Chancelade-type and related axillary border morphologies in the modern population studied. For example, females of 18-30 years of age exhibit approximately 40% incidence of Types 2-5, and at ages 30-40 this incidence rises to 60%. It was also observed that usually there is a greater incidence of Chancelade and related morphologies on the right side in the Arikara sample. Males 30-40 exhibit a 71% incidence of Types 2-5 on the right side as do females over 40. As the expected frequencies with regard to morphological patterns should be approximately a 50-50 distribution with respect to side, the indications are that morphological changes occur through greater use or exertion. These results agree with the contention of Bainbridge and Genoves (1956), Vallois (1932) and Trinkaus (in press) that the Chancelade-type morphology is indicative of greater exertion in the shoulder area. This suggestion is based on the findings of much greater incidences of Chancelade-type borders among non-technologically advanced groups (von Eickstedt 1925, Vallois 1932). One expects that greater physical exertion is necessitated by the lifeways of these groups than in technologically advanced societies. Conversely, European groups generally exhibit smaller frequencies of Chancelade-type axillary borders.

However, a cautious approach should be taken to the conclusion that the morphology of the axillary border of the scapula is purely a result of muscular exertion as expressed on the bone. It may be that thicker, laterally turned, or, possibly, the Chancelade (bisulcate) pattern is to some degree a genetic factor selected for in populations where heavy use of the upper limbs is necessary. Thus, individuals born with stronger scapulae would have better potential for performing strenuous tasks and be better equipped for a rugged way of life.

Hrdlička (1942a:77) believed there is a tendency to a particular form of bone being inherited with ". . . the result subject to functional modification." Thus, the forms on the axillary border may be partly determined phylogenetically and partly acquired ontogenetically.

Upon investigating juvenile scapulae it was seen that many give a vague appearance of a tendency toward a ventral sulcus; some few, however, appeared as though a bisulcate pattern was a possibility for later development.

Vallois (1932) considered the Chancelade-type border as corresponding to very powerful movements of elevation of the arms. As for the Neandertal type, Vallois (1932) suggested that the teres minor muscle may have received greater stress due to greater usage of this muscle in activities requiring more frequent lateral rotation rather than medial rotation.

In a functional analysis of the *raison d'être* of the Neandertal type of axillary border, Trinkaus (in press) maintained that the teres minor muscle was more greatly developed in Neandertals because it assisted in resisting the powerfully developed deltoid muscle of

Neandertals while maintaining the humeral head in the glenoid fossa during abduction. It is known that Neandertals had powerful deltoid muscles, as enlarged deltoid tuberosities are found on Neandertal humeri (Endo and Kimura 1970). This part of the interpretation may be questioned, as subscapularis (the ventrally inserted muscle) also aids in providing the force tending to pull down the humeral head along with teres minor and infraspinatus (Morris and Schaeffer 1953). Subscapularis, infraspinatus and teres minor are a "muscle force couple" which acts continuously as a functional group during abduction as depressors of the humeral head while supraspinatus and deltoid are elevating the humerus (Inman et al. 1944, Johnston et al. 1958).

Trinkaus does say, however, that this resistive action against deltoid is not in itself sufficient to explain the apparently greater development of teres minor in Neandertals. The teres minor muscle, infraspinatus, and posterior fibers of the deltoid muscle act as lateral rotators of the humerus (Johnston et al. 1958) and in this role teres minor had to resist the strongly developed medial rotators of the humerus: latissimus dorsi, pectoralis major, and teres major. These muscles are also the primary humeral adductors. The medial rotation of these muscles during adduction were necessarily counterbalanced by strengthened lateral rotators in order that a precise yet powerful humeral adduction takes place. Greater use of infraspinatus by Neandertals is possibly indicated as Heim (1974) mentioned that the La Ferrassie specimens had deep infraspinous fossae. However, the subscapularis fossae were also very well developed in these specimens, suggesting that subscapularis was also greatly used. Subscapularis, additionally,

is an aid in medial rotation when the arm is at the side (Johnston et al. 1958).

Trinkaus' analysis possibly offers some clues to the understanding of the morphology of the axillary border of Neandertals. However, this writer has reservations concerning Trinkaus' statement

The subsequent evolution of the border to the bisulcate pattern of the . . . Upper Paleolithic hominids and the ventral sulcus pattern characteristic of recent humans MERELY indicates a steady decrease in the levels of biomechanical stress at the hominid shoulder in agreement with the corresponding increases in the level of cultural adaptive efficiency during the Upper Pleistocene (Trinkaus in press).

This appears to be too facile an explanation, although Trinkaus notes that there is probably an ontogenetic explanation rather than the phylogenetic one as implied by other authors. On the basis of observations in this work on modern material it is suggested that the Neandertal morphology may be ontogenetically explained. However, factors other than changes in cultural level and simple biomechanical stress should be considered.

A number of other factors seem related to the morphology of the Neandertal axillary border. It was found that there is some correlation between wider humeral heads and Chancelade and related morphologies. Thus, it is possible that the relationship between the wider humeral head and the more laterally deviating glenoid fossa of Neandertals may have been contributing factors in creating the high incidence of dorsal sulci in this group. These slight differences in scapulohumeral relationships may have altered the amount of stress of certain muscles in the scapulohumeral group. Another possibly relevant factor is the cranial deviation of the humeral head with relation to the shaft in

Neandertals. The head/shaft angle was measured in the modern populations used in this study and it was found that there is some positive association between non-ventral morphologies, especially the Chancelade, and high-angled humeral heads.

Other associations within the scapula were investigated but none were found to be informative, with the possible exception of the morphology of the infraglenoid tubercle and general muscularity. More robust tubercles and more muscular scapulae and humeri seem somewhat positively associated with non-ventral morphologies. Axillo-glenoid angles, expected to be highly associated with Chancelade and related morphologies, were not conclusively so, especially in females. However, there is also an exception to the tendency of high axillo-glenoid angles in Neandertals. Tabun I, the only certain female Neandertal with a preserved scapula, has an axillo-glenoid angle much lower than other Neandertals', and an angle close to the mean of modern men.

It also appears logical that the morphology of the rib cage of Neandertals was a crucial factor influencing the morphology of the axillary border of the scapula. The shape of the thorax in Neandertals was different from that of modern man, and this difference may have altered the relationships between bones and muscles in the shoulder area. Of course, this crucial factor, a barrel-shaped chest as in Neandertals, is lacking in the comparative sample used in this study and thus could not be directly tested.

The barrel-shaped thorax of Neandertals is indicated by the fact that curvature of the ribs is less pronounced in Neandertals than in modern men (Hrdlička 1930, Endo and Kimura 1970). Thus, the Neandertal

scapula was probably positioned slightly differently with respect to the rib cage thus altering its position with relation to the humerus somewhat. A more cranially directed humeral head and a more laterally inclined glenoid fossa may have been a result of the particular scapulo-humeral juxtaposition resulting from the shape of the rib cage; or, alternatively, the head/fossa relationship may have previously existed and made an additional contribution to the musculoskeletal shifts in emphasis.

It appears that in Neandertals the vertebral border of the scapula did not lie as flat in relation to the rib cage as it does in modern man. This would have altered the antero-posterior orientation of the glenoid fossa. The glenoid fossa probably faced more ventro-laterally than it does in modern man. The humeral head presumably bore a differing relationship to the glenoid cavity than is the case now, which would have resulted in alterations in the muscular relationships. It seems plausible that this change in scapulohumeral musculoskeletal relationships may have increased the magnitude of the stress upon the teres minor muscle in Neandertals.

With the flattening of the rib cage, the scapula migrated dorsally, thus altering the angle which the scapula bore to the rib cage. This situation would, in turn, alter the relationship between the humeral head and the glenoid fossa and possibly alter (slightly) the position of muscle attachments on the bone in order to maintain original function. With the shifting of the scapula's position on the chest wall the positioning of the humerus was affected as the humerus would have followed the scapular shift (Inman et al. 1944). These changes and



shifting relationships are apparently analogous to the situation that occurred in primate evolution--from ape to man--with the erect posture concurrently evolving. Supporting the aforementioned interpretation is the factor of relatively weak humeral torsion that is found in Neandertals (Howell 1957). Humeral torsion gradually increases with ascent of the phylogenetic tree from the monkeys through the apes to man (Krahl and Evan 1945).

Other factors which should be taken into consideration are the specific demands of the cultural adaptive level and what these demands might mean in terms of how the muscles were used. The earlier discussion concerning muscle usage considered the level of general muscular exertion which might be necessitated by a harsh way of life. General robustness of the Neandertal skeletal material attests to this way of life. The subsistence pattern of Neandertals may have demanded not only greater biomechanical stress at the shoulder joint but also habitual kinds of movements which became unnecessary in later levels of cultural adaptation. Vallois (1932) suggested that, since one of the functions of the teres minor muscle is to rotate the humerus laterally, perhaps certain aspects of the culture necessitated more frequent or more strenuous use of the lateral rotators than in modern men. This theory complements the earlier explanation (Trinkaus in press) of the stronger use of the lateral rotators in order for precise and power adduction to take place.

The speculation in this thesis is that a habitual way of using certain tools or weapons in the Middle Paleolithic (and possible earlier, as well) may have influenced stronger development of the teres minor

muscle. For example, a particular way of heaving or using a spear may have differed from later usage and may have emphasized the teres minor muscle; or, the morphology of the thorax area may have necessitated stronger development of teres minor in order that the weapon be properly heaved. The advent of the spear throwers or atlatl in the Upper Paleolithic may have diluted the necessity for strong use of certain shoulder muscles in hunting and other activities.

It appears that a combination of factors contributed to the changes in morphology seen on the axillary border of the scapula through time.

## II. SUMMARY

Discussion of Neandertal man's place in anatomically modern man's ancestry has only occasionally shifted to below the cranium. Two post-cranial areas are morphologically different from anatomically modern man: the morphology of the superior pubic ramus of the innominate, and that of the axillary border of the scapula. This thesis has been concerned with the latter problem. Whereas in Neandertals a *sulcus dorso-axillaris* is seen in two-thirds of the known remains, this situation is seldom found in modern man, where the sulcus is most frequently *ventro-axillaris*. This study has been an attempt to analyze the relationships of scapular features with a view to elucidating the possible causes of the sulcus changes that occurred between Neandertal and anatomically modern man. The factors that may have caused the shift from dorsal to ventral sulcus, with the intermediate form of the bisulcate border assisting in the transition, are discussed.

Although the comparative skeletal material used in this study belonged to modern *Homo sapiens*, measurements and morphological information concerning Neandertal skeletal material was available from the literature. The investigator endeavored to duplicate the methods of measuring the original Neandertal material as described in the literature, in order to obtain comparable measurements.

The morphology of the axillary border was grouped into five classifications in this investigation. The frequencies of each of these morphological types was recoded with regard to the findings in the two sexes, the two sides and three age groups (18-30 year olds, 30-40 year olds, and individuals over 40 years old). Morphological evaluations were also made with regard to general robusticity of the scapula and associated humerus, robusticity of the infraglenoid tubercle, and depth of the glenoid fossa. An attempt was made to relate these morphologies to the varying morphologies seen on the axillary border. Correlations with morphologies seen on the axillary border were also sought for fossa indices, humeral head indices, axillo-glenoid angles, and humeral head/shaft angles.

This study supports the idea that the greater development of the teres minor muscle, as evidenced by the greater incidence of the Chancelade pattern, is a product of increased demands upon the upper limb. This idea is further corroborated by Trinkaus' findings (in press) of a greater incidence of the Chancelade or bisulcate type on the right scapula; as well as similar findings of this thesis. This thesis has established that there is somewhat greater incidence of the Chancelade type on the right side and a definite increase with age in the occurrence of this morphological type.

The suggestion, implied or stated, that Neandertal man was not in the direct lineage of modern man due to the fact that his axillary border was usually so different from recent man's seems untenable. This idea seems especially untenable when one considers that the Chancelade or bisulcate axillary border was seen in several Neandertal scapulae, with greater frequency in Upper Paleolithic skeletal material, and is still seen in reasonable frequencies in modern man today. Thus it seems that a gradual transition had occurred between types.


One may safely assume, therefore, that the Neandertal level of cultural adaptation made greater demands upon the musculature of the upper limbs which caused larger development of the teres minor muscle than is seen in later hominids with more advanced technologies. Intrinsic to this assumption is the possibility that the teres minor muscle was greatly stressed in its role as a lateral rotator of the humerus and powerfully resisted the medial rotators in order that precise and powerful adduction could take place.

Additionally, variations in scapulohumeral musculoskeletal juxtaposition must be considered. The thoracic area was quite differently shaped in Neandertals (Hrdlička 1930). The more barrel-shaped chest of Neandertals may have produced differing relationships between the scapula and humerus and in the muscular relationships between these bones. The possibility of studying the effect of more barrel-shaped chests on scapulohumeral relationships was not feasible, but the relationship between wider and more cranially inclined humeral heads to border types was studied. It was found that a somewhat positive relationship seems to exist between wider and more cranially deviated

humeral heads and the Chancelade morphologies. This confirmed suspicions that variables in scapulohumeral relationships may influence muscular stress, thus creating varying border types.

### III. RECOMMENDATIONS FOR FURTHER STUDY

The present study might be expanded by the study of additional skeletal material, especially of other racial groups. Additionally, further study of other features of the shoulder joint and thoracic area should be considered. It would also be instructive to study scapular changes in living animals when transections of various scapular muscles had been made in the newborn. From Wolffson's (1950) experiments performed on rats, it was seen that muscular forces play a large role in the production of scapular shape or morphologies.



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## VITA

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Carol began her graduate work in Anthropology at The University of Tennessee in the fall of 1971. From September of 1972 to September of 1973, she and her family resided in Mainz, Germany. Carol spent that year attending lectures in the Institutes of Prehistory and Anthropology at the University of Mainz, in addition to travels in many European countries. With the return of the family to Tennessee in 1973, she resumed her graduate studies at The University of Tennessee. The Master of Arts degree with a major in Anthropology was awarded in June, 1976.

She is married to Dr. Peter F. Dittner, a physicist, who is a research staff member at the Oak Ridge National Laboratory. The couple live in Oak Ridge and have two children: Amy, 15 and Steven, 12.