STRATIGRAPHY OF THE DIE KELDERS CAVE 1 (WESTERN CAPE PROVINCE, SOUTH AFRICA) LATER STONE AGE DEPOSITS

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Die Kelders Cave 1 (DK1) contains one of the few large, deeply stratified prehistoric deposits containing the remains of domesticated animals in the Western Cape Province of South Africa (see Figure 1). First excavated in the late 1960's and 1970's, (Schweitzer 1979), Die Kelders yielded both Middle Stone Age (MSA) and Later Stone Age (LSA) material. The LSA occupation, containing Late Ceramic Wilton artifacts, presented a rare glimpse of the period immediately preceding the arrival of domestic livestock in South Africa and an equally rare early pastoralist occupation. The timing of occupation, depth of the deposit and richness of the Die Kelders artifact assemblage contribute to the importance of the site, but the cave also yielded botanical remains and a very large assemblage of well-preserved archaeofaunal remains, including a wide array of shellfish, terrestrial and marine mammals, fish, birds and reptiles (Schweitzer 1979). However, problems surround the provenience and dating of supposedly-early domestic stock remains discovered during the first excavations, and these problems contribute to the continuing controversy surrounding the advent of herding economies in South Africa (e.g. Bousman 1998; Henshilwood 1996; Sadr 1998; Sealy and Yates 1994, 1996; Smith et. al. 1991; Smith 1998). The site and the regional debate have broader implications for understanding the pattern and process of the introduction of domestic animals and economies to regions previously inhabited only by hunter-gatherers. The Western Cape, being at the southernmost tip of Africa, is one of the last hold-outs in the spread of pasturalism throughout the continent. This, along with the high quality of the sites and the relative density of the record, make this region a potential critical record for advancing our understanding of the spread of domestication to hunter-gatherers.

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Subsequent excavations in the 1990's expanded the excavated area and yielded another large sample of well-preserved artifactual, botanical and archaeofaunal material. These later excavations were conducted by a joint team lead by Graham Avery, Frederick Grine, Richard Klein, and Curtis Marean. For the sake of brevity and clarity, we will refer to these as the Avery excavations. These later excavations proceeded more slowly and identified finer stratigraphic distinctions than the Schweitzer excavations. The MSA deposits and analyses have been presented in detail (Marean, 2000), but to date the LSA from the Avery excavations has received only preliminary description (Avery et al. 1997). The depth and structure of the LSA deposits presented the opportunity to ask new, fine-grained diachronic questions about the development of pastoralism from its advent in the Western Cape, but until now, the identified stratigraphic units had not been analyzed or placed into a stratigraphic sequence. This meant that the pastoralist-era material from the more recent excavations could be analyzed only as a single collection; analyses of change over time were impossible, even though the deposit was deep and well-stratified, if complex. This paper presents that LSA stratigraphic sequence.

Based on excavators' notes, section drawings and photographs, we have constructed a chronological and stratigraphic LSA sequence for the large, western block of the Avery excavations (ca. 27 square meters- Figure 2). We present the hitherto unpublished LSA sequence constructed for the eastern block of excavations, and provide nine new radiocarbon dates for these deposits, two from the eastern block, and the seven from the western block (see Figure 2 and Table 4). Finally, we discuss the relevance of our sequence for understanding the ages of the domestic sheep remains recovered from DK1.

THE LSA EXCAVATIONS AT DK1, 1992-1995

The Schweitzer excavations at DK1 lasted seven seasons, beginning in 1969, and continuing until 1973 (Figure 2). He divided the LSA stratigraphy into 12 layers, numbered in ascending order from top to bottom. These are well described in a monograph (Schweitzer 1979).

Over the course of three seasons (1992, 1993, 1995) (Avery, et al. 1997, Marean et. al. 2000) the Avery excavations recovered a considerable amount of LSA and MSA material. These excavations were situated on the east and west margins of Schweitzer's earlier trenches (Figure 2). The later excavators recorded 359 Later Stone Age depositional units over the course of two seasons, with only MSA material recovered during the third season. Radiocarbon dates from both campaigns suggest that the levels contemporary with prehistoric pastoralism at the site span between ca. 2000 and 1100 ^{14}C years ago (Schweitzer 1979: 126-7, and below) -a relatively short span of time containing a rich deposit. During the Avery excavations, different teams worked on either side of the original Schweitzer excavations. Graham Avery and Frederick Grine were primarily responsible for the western block, while Curtis Marean and Michael Lenardi excavated the eastern block.

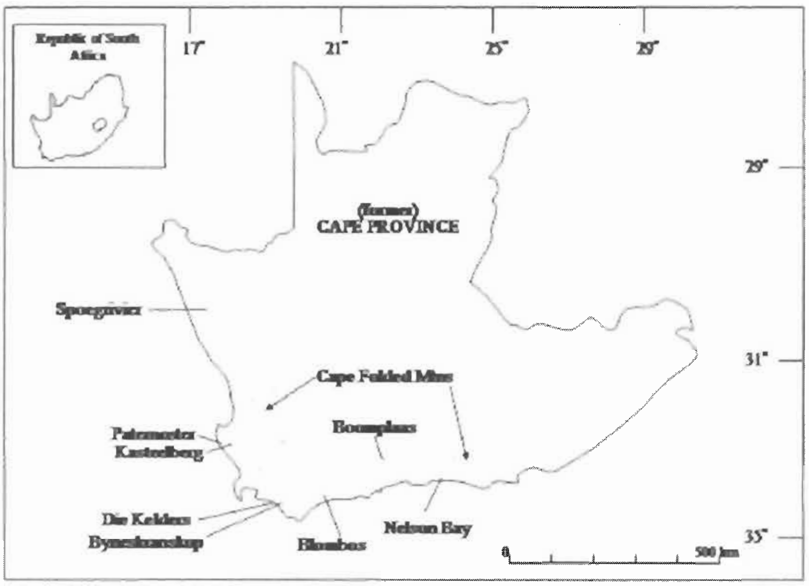
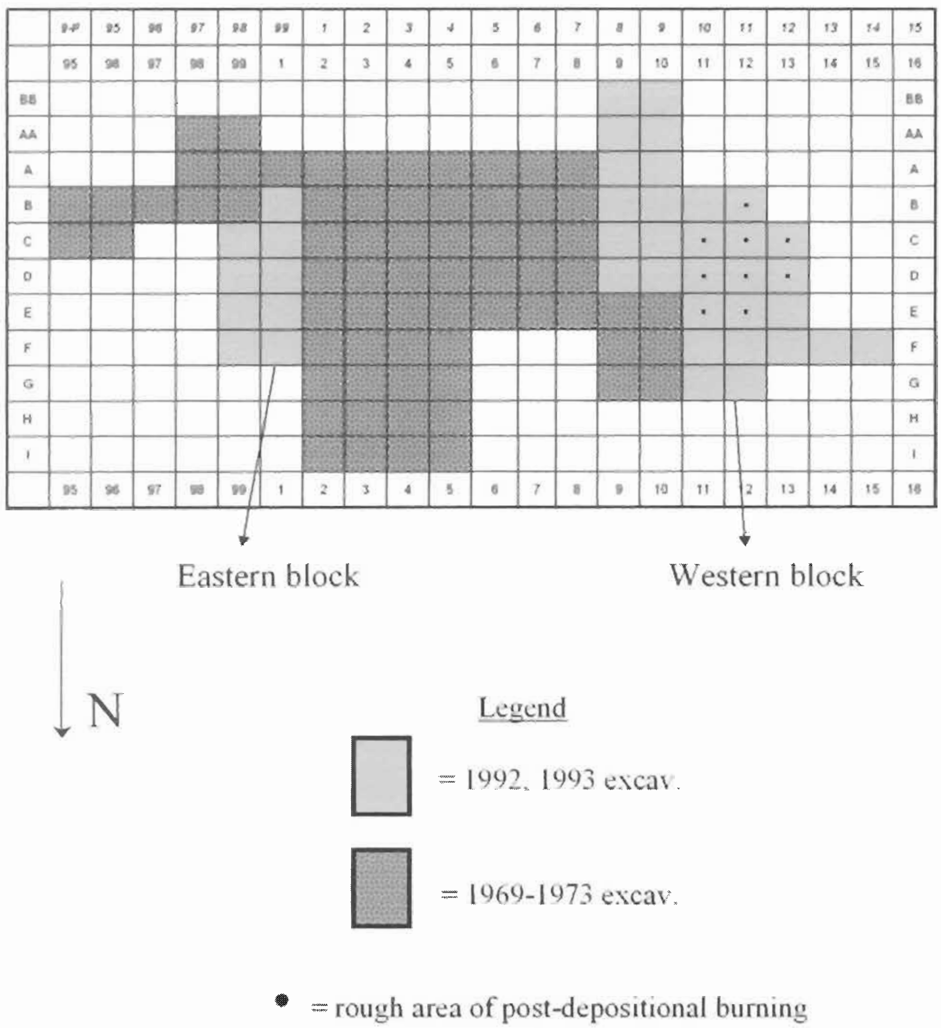


Figure 1: Location of DK1 and other prehistoric sites containing the remains of domestic mammals. (Modified from Marean et. al. 2000)



‡Italic numbers indicate Schweitzer's grid, which is offset 1 meter to the east of Avery et. al.'s grid.

Figure 2: LSA excavations at DK1.

Individual excavators named these finely stratified deposits according to an alphanumeric system where AAA was the first named unit, AAB the second, and so on. This system is common in South Africa and is designed to deal with the complex stratigraphy of shell middens, where it is very common to find very small and discrete lenses of material. It is important to recognize that these entities, hereafter referred to as stratigraphic units, represent excavators' *hypotheses* at the moment of excavation, as each unit was encountered or perceived.

The excavators attempted to trace these units to their furthest extent, although this was not always successful. More than one excavator worked at a time, and, with very few exceptions, stratigraphic unit names given in 1992 were not retained in 1993. As a result, the label AAA denotes the same deposit wherever that label appears, but AKK and AGG might pertain to the same deposit, simply because of the way in which names were assigned to depositional units.

A unit could be subdivided into sub-units by appending roman numerals to the end of the unit name. Thus, a perceived sub-unit of AAA would be named AAAi, the next sub-unit named AAAii, and so on. Sub-units might be designated when excavators were tentative about a perceived difference in color, texture, etc. Sub-units could also be designated when deep, homogeneous deposits required arbitrary division or when a change in color or texture was apparent, but believed to be a part, or facies, of a larger depositional unit. Ultimately, then, the goal is to aggregate these sub-units into larger stratigraphic aggregates, while at the same time retaining the ability to analyze very finely resolved field observations.

Site photographs often depict the locations of stratigraphic units in the profile walls. Wherever the bottom of a stratigraphic unit intersected the profile wall, the excavators labeled a tag with the appropriate unit name, ran a pin or nail through the tag or label, and thrust the pin into the wall at the point where the base of the unit met that wall. Tag positions were commonly, but not always noted on profile drawings. The horizontal position and shape of the stratigraphic units was drawn on a plan, and elevations were taken at multiple locations along the base of the stratigraphic unit.

Archaeological material from these units was bagged and labeled with provenience information and a lot number designated to track the material after recovery and curation. For a given stratigraphic unit, such as AAAi, all the material from each quadrant (NW, NE, SW, SE) of each square received a unique lot number each day. Thus, material collected on the 12^{th} of March from the NW Quad of Square B12, unit AAAi might have received lot number 700. If the excavator then encountered AAAi in the NE quad, the material he or she collected from the AAAi, NE Quad would be assigned the next unused lot number. If AAAi continued into neighboring squares, new lot numbers would be assigned in each quad where AAAi was recognized. Each lot number was used only once throughout the entire site. As a result, all but the smallest stratigraphic units are comprised of multiple lot numbers. The result of all this is that all finds can be located to a rather precise horizontal and vertical provenience through the use of the lot number. However, the proliferation of lots makes the aggregation process that much more difficult.

ANALYSIS PROCEDURES

As discussed previously, the excavators took notes for each unit they encountered and attempted to trace units across squares when excavation proceeded from one square to its neighbor, but unit names from 1992 were not retained in 1993. In order to create a sequence suitable for diachronic analyses, it was necessary to devise: 1) a master chronological sequence of the smallest possible stratigraphic units, and, 2) stratigraphic connections between the 1992 and 1993 excavations, with their two different sets of unit names. We were ultimately unable to correlate the stratigraphy from the western block with Schweitzer's sequence, but Marean and Lenardi did devise such a correlation for the eastern block, presented below.

Stratigraphic analyses (Marean and Lenardi unpub.) were completed for the eastern block of deposits, which were of lesser extent, less complex and less disturbed than was the case in the western block. Marean and Lenardi's interpretations are synthesized and presented here.

In the case of the western excavations, the site records described below existed in the form of disconnected, independent components and the ways in which these descriptions fit together was sometimes ambiguous. For instance, it was not possible to understand how the material in the squares A10, B10, C10, and D10 related to the material from A11, B11, C11 and D11, these two rows of squares each being represented by independent profile drawings.

A large combustion feature transformed and disturbed a large portion of the western block (Fig. 2), compounding the complexity of the strata. As a result, the excavators were unsure as to whether they had successfully traced their stratigraphic units through this large feature. The feature, thought to be the result of post-depositional smoldering of buried organic matter, takes the form of a very large, relatively homogeneous grey body. Within this body, all the material burned in a reducing atmosphere, leaving behind grey sediment, grey and white calcined bone and grey, fragmented shell. It also led to some slumping of the deposit. Based on the profile photographs, the area of this disturbance is estimated to be roughly six square meters. Any master sequence must include this large area but also account for the disturbance.

In order to accomplish these goals, we began by copying all the original excavation notes and profile drawings pertaining to the 1992-1993 LSA excavations. The excavation notes had also been typed up by a museum worker, and these files were checked against the originals. Next, all profile drawings were scanned as high resolution images, as were a selection of slide photos of the excavation, again as high resolution files. This analysis is based on all three classes of evidence: notes, profile drawings and profile photographs.

We next reviewed the excavation notes. The notes commonly suggested whether a unit underlay or overlay other named units, and we attempted to re-construct relationships as best we could, based on these notes. With the general orientation provided by this textual evidence, we then reviewed the scanned photos and identified those in which the tags were legible. Matching profile drawings to photos of the same profile, we drew strata as indicated in the pencil-and-paper profile onto the digital photographs. This made it possible to see the stratigraphic characteristics noted by the excavators, and to record the individual stratigraphic units that comprised the final strata, hereafter referred to as Layers or Levels. The next step was to trace these layers across the disparate profiles. The final profile drawings and the photographs from which they were derived are presented in Figures 3-21. Not all the excavated layers were captured in photographs, nor were all the possible sections or squares, but nearly all levels are depicted in at least one figure. Those few levels which are not pictured in any figure will be noted as such in the description of that level. Squares that are all in a row or column will occasionally be referred to as '10 line,' or 'B line,' in order to conveniently reference a series of squares.

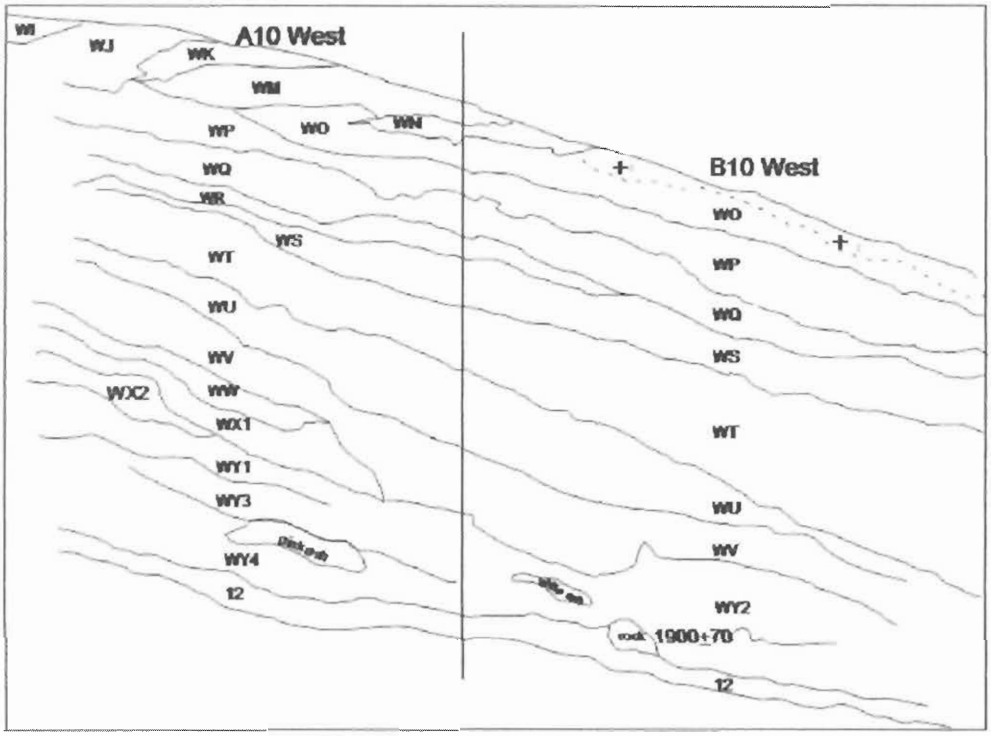


Figure 3: Diagram of A10 and B10 West Section. Western block photographs were taken by Graham Avery and Fred Grine.

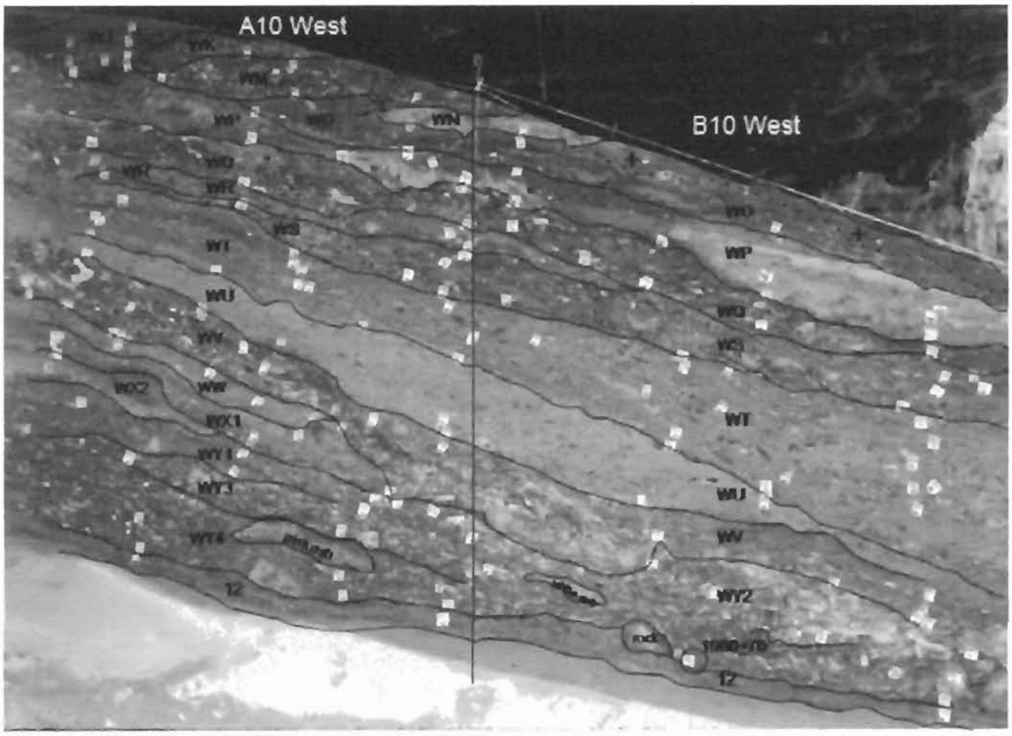


Figure 4: A10 and B10 West section photograph

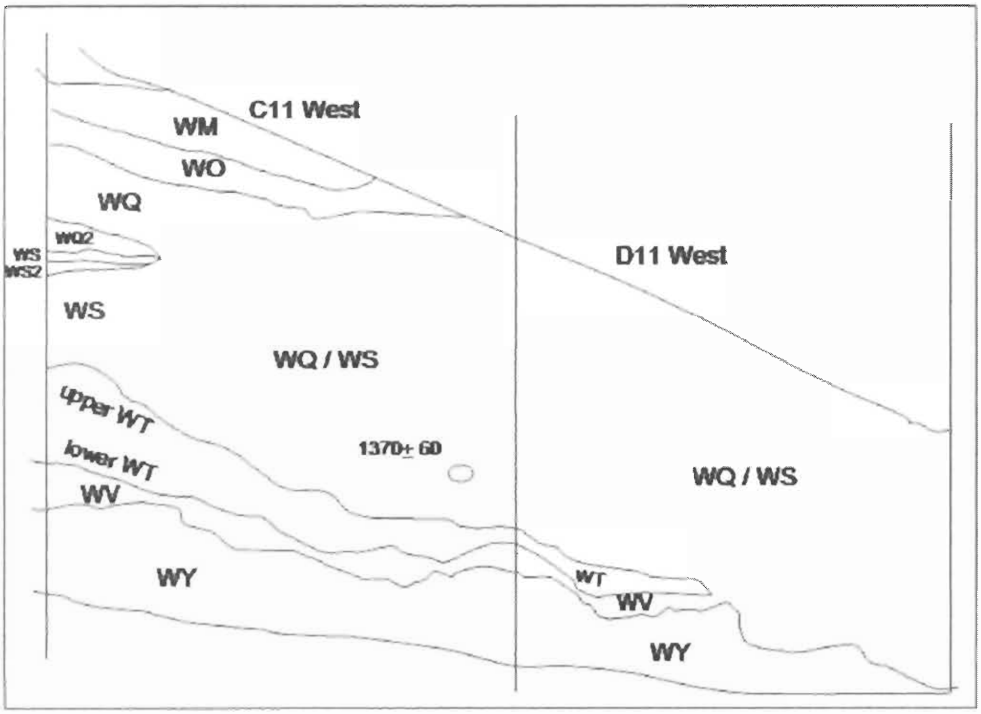


Figure 5: Diagram of C11 and D11 West profile

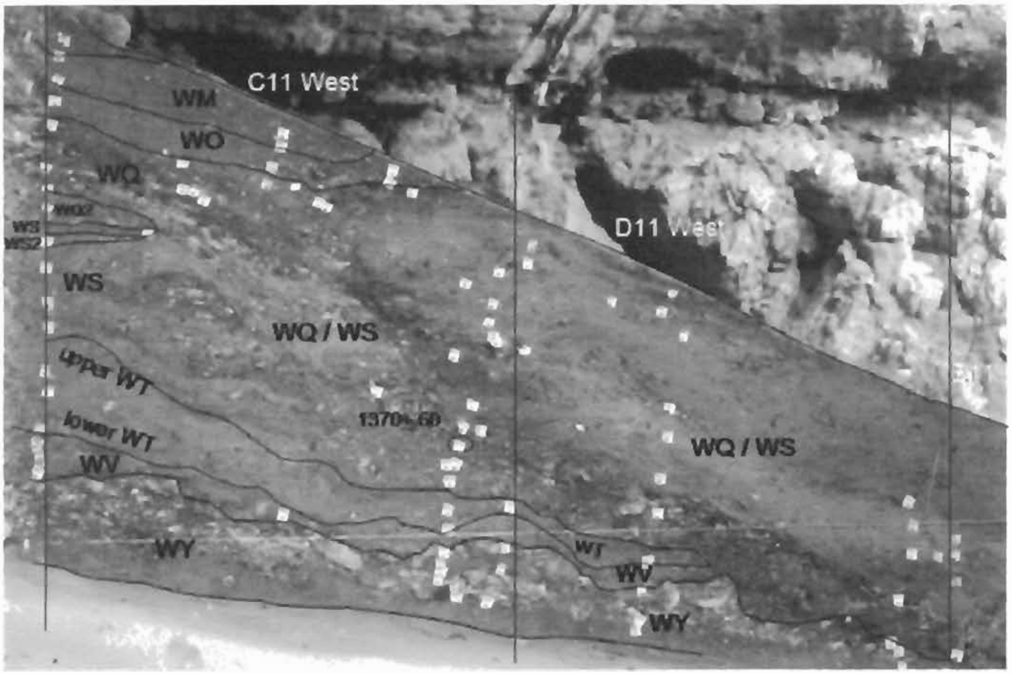


Figure 6: C11, D11 West section photograph

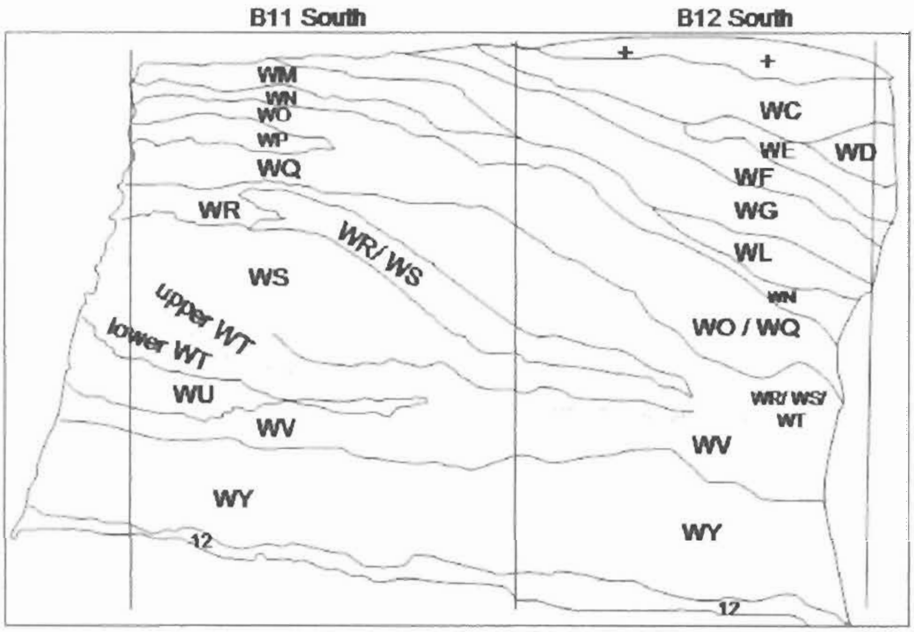


Figure 7: Diagram of B11 and B12 South profile

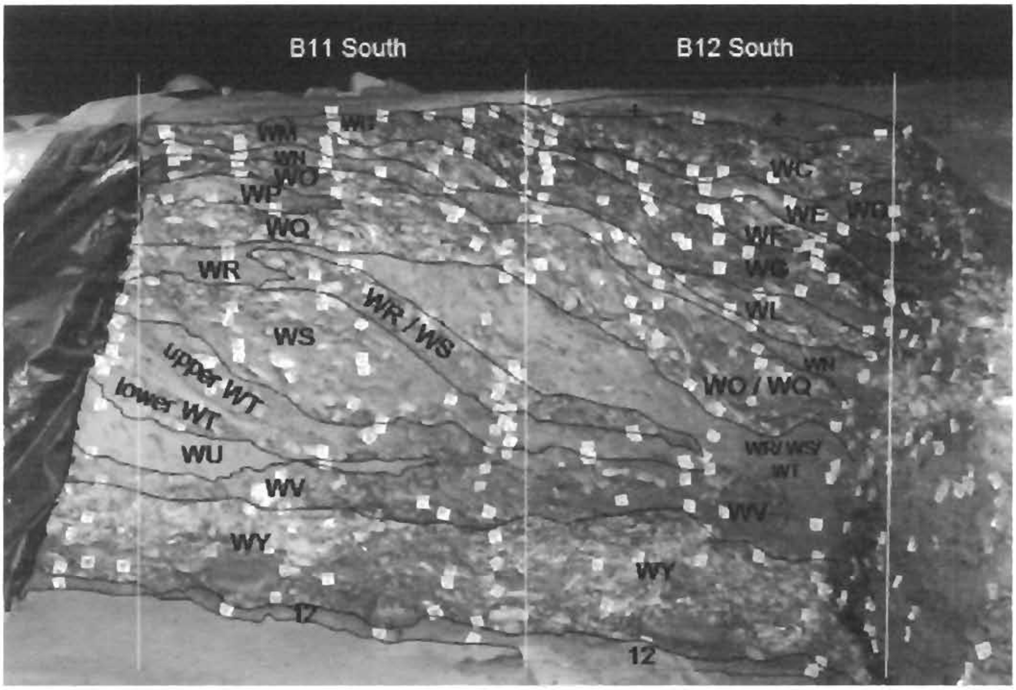


Figure 8: B11 and B12 South section photograph

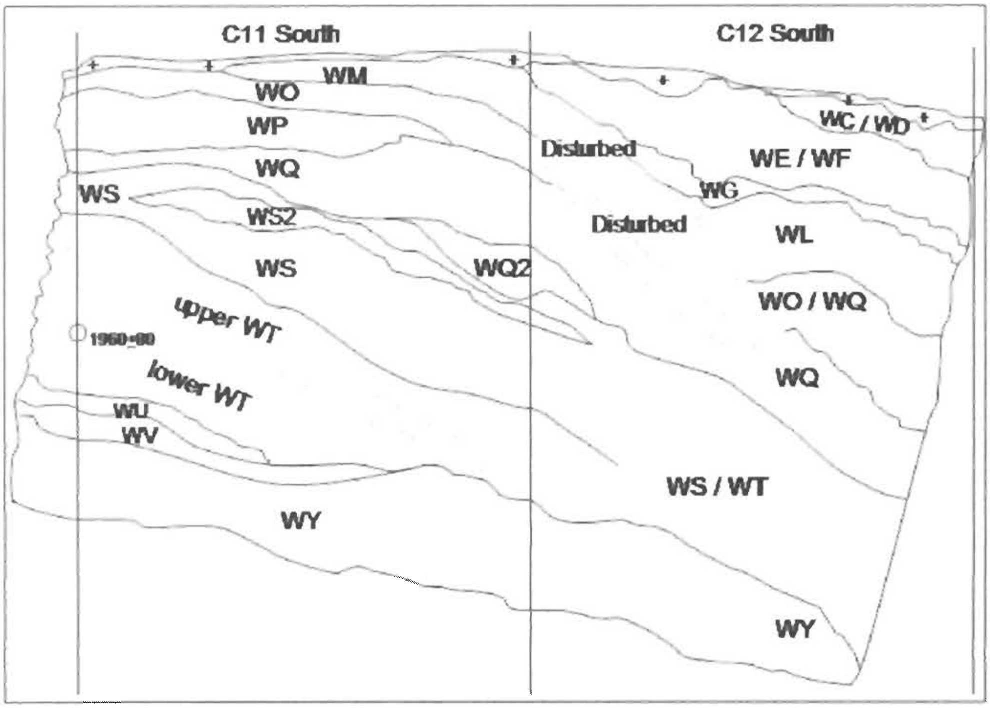


Figure 9: Diagram of C11 and C12 South profile

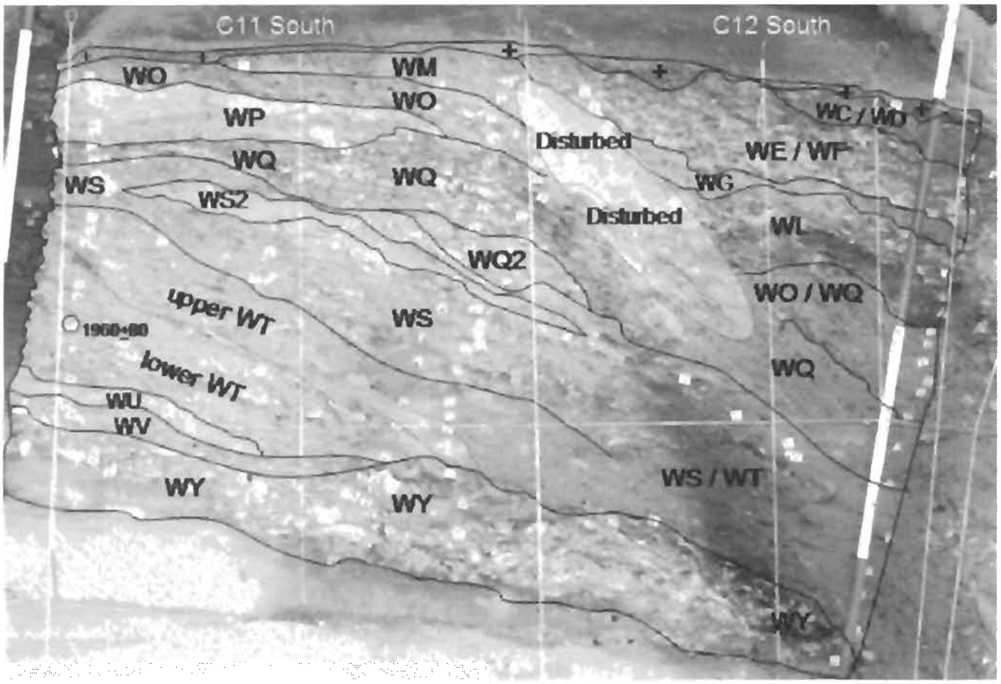


Figure 10: C11 and C12 South section photograph

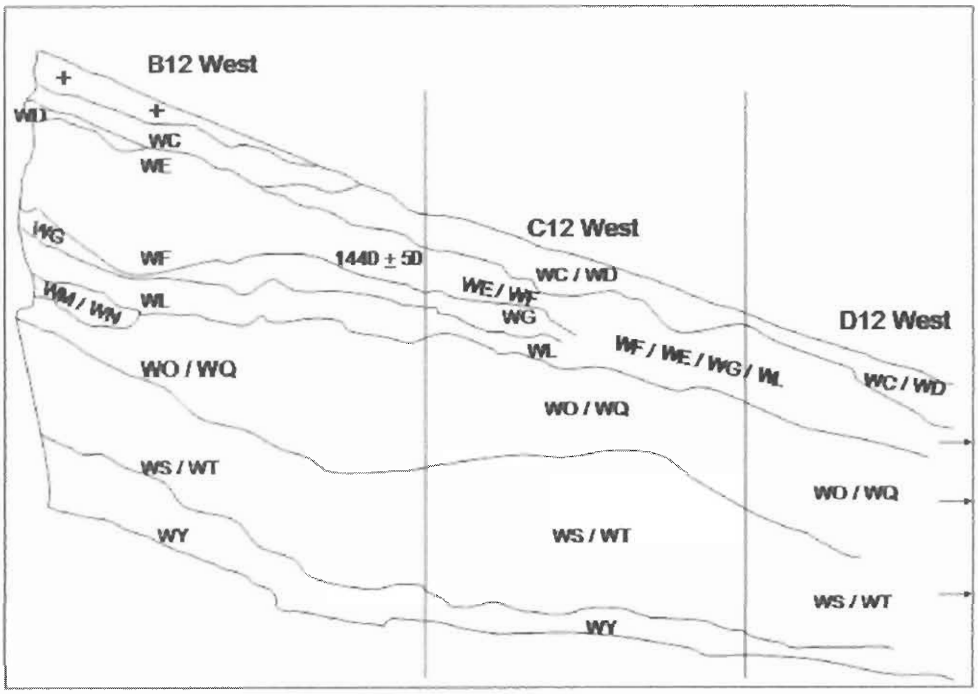


Figure 11: Diagram of B12, C12 and D12 West profile

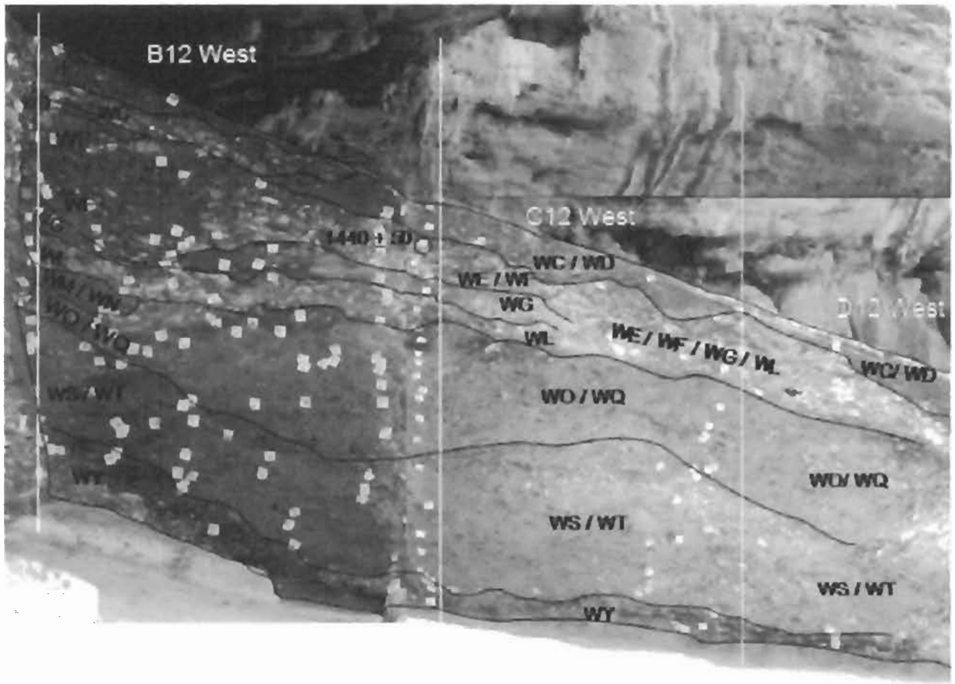


Figure 12: B12, C12 and D12 West section photograph

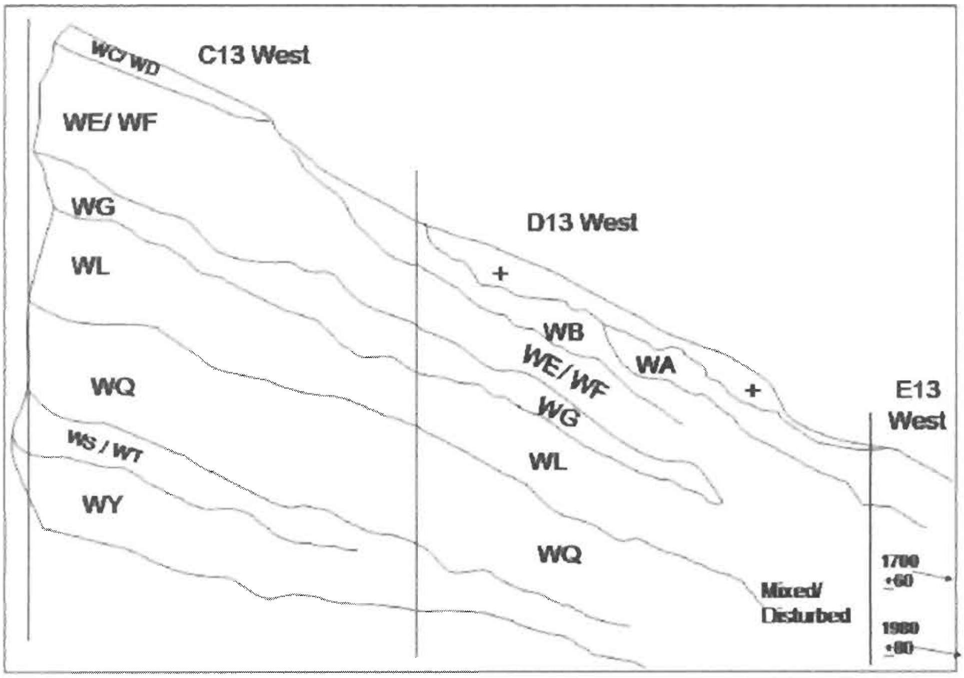


Figure 13: Diagram of C13 and D13 West profile

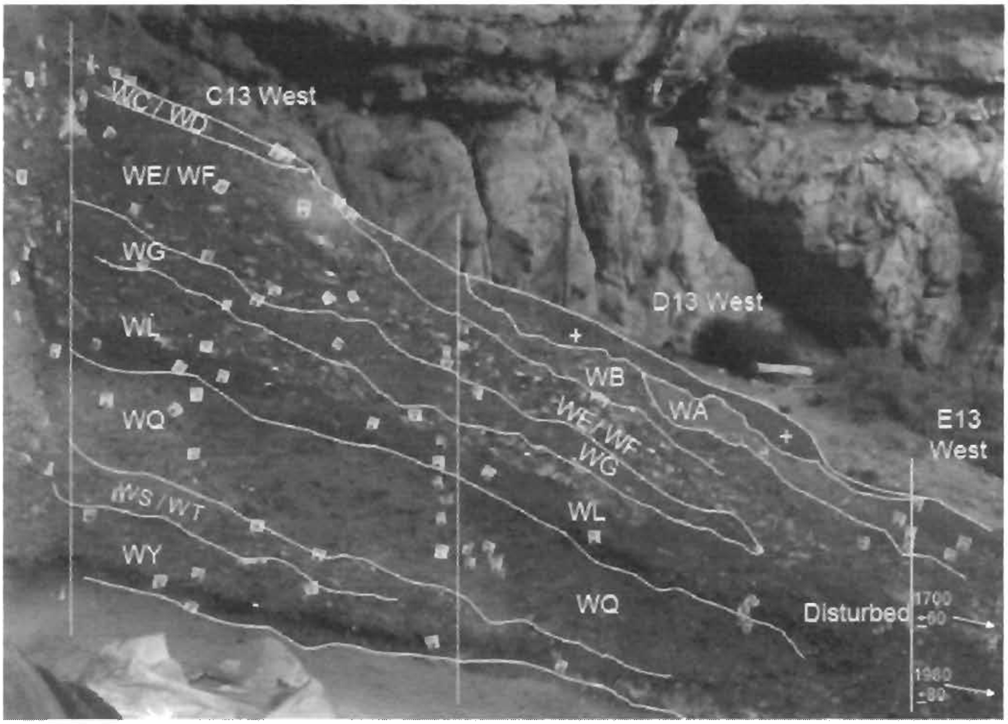


Figure 14: C13 and D13 West section photograph

The stratigraphic connections we have made between profiles are based on visual similarity (color, texture, shell orientation, contents, etc.), excavators' description, consistent vertical position, and tag locations. In some cases, strata recorded on drawings could not be adequately traced on photos due to lack of visual referents compounded by a lack of tag positions recorded on the drawings. Photographs record and deliver less visual information than is available first-hand, but if both tag positions and visual referents were lacking, there was no way to know which stratigraphic units were included within the layer/stratum as depicted in the drawing. In these situations, with insufficient data to discern the individual stratum, strata were lumped as much as necessary to accommodate the uncertainty.

In cases where the inspection of photographs suggested relationships that did not conform to those posited by the drawings, we considered the drawings to be the authoritative source. However, there were some instances where the drawings could not be reconciled with one another. The only major case of this occurs at the southern end of the post-depositionally burned and slumped area. This occurs in squares B12 and C12, carrying northwards through the D and E rows of columns 11, 12 and 13 (see Fig. 2). Squares C11 and C12 were excavated in 1992, while B11, B12, and C13 were excavated in 1993. In the former case, the resultant profile drawing illustrates C11 and C12 South, as well as C12 through F12. The neighboring squares, dug in 1993, are depicted by the excavators in a profile drawing that illustrates B11 and B12 South, B12 West, C13 South, and C13, D13 and E 13 West. These two drawings could not be reconciled without changes to one or the other version.

As mentioned above, the south wall C11 and C12, and west walls of C12, D12, E12 and F12, all excavated in 1992, were depicted in one profile drawing. A second drawing, from 1993, showed the south walls of B11 and B12, west wall of B12, south wall of C13 and west wall of C13, D13 and E13. The crux of the confusion appears in the south wall drawings and photos of B12 and C12. The 1993 excavators of B11 and B12 showed the strata here named WM, WN, WO, WP, WQ, WR, WS and WT (hereafter, "WM through WT") as pinching out and/or diving steeply to the west. They saw these strata as overlain by 'new' strata, here labeled WC, WD, WE, WF and WG (hereafter, "WC through WG"). These strata can clearly be seen to continue to the north, visible in the B12 west wall and C13 south.

In contrast, the 1992 excavators of C11 and C12 saw layers WM through WT continuing laterally to the west, without the severe dive and without termination. The implications of this disagreement are immense: the 1993 argument introduces more recent strata and puts the older ones deeper in the column. The 1992 argument maintained that the same, older strata continued laterally without interruption and therefore remained higher in the sediment profile. This has consequences for every excavated square from the 12 line, westward-eleven square meters in all.

Looking specifically at C12 south wall (Figs. 9 and 10), we can see the beginnings of the massive burned area disturbance in the eastern half, where the interface between layers in the upper half is churned and obscured. The 1992 excavators interpreted this as localized disturbance, and maintained that the layers present in C11 continued on the west side of the disturbance. The first suggestion that this reconstruction may need reconsideration comes from the character of Level WE/WF. The base of this layer appears to slope up to, and become truncated by, the modern surface. This is an unlikely structure if Levels WE/WF is, in fact, the westward continuation of WO.

The photograph of the B11 and B12 south wall (Figs. 7 and 8) shows clearer stratification because this wall is unburned; the burning and disturbance begin in B12, north of the south wall. In this photograph, layers WM through WT dive downwards to the west, and are themselves overlain by the 'new' layers WL, WG, WF,WE, WD, WC. If we turn the corner and view the B12 *west* wall (Figs. 11 and 12), we see how the layers apparent in B12 south continue to the north, intersecting the C12 south wall. The disturbance seen in the C12 south wall happens to be located so that it obscures the appearance of the 'new' levels, from WL on the lower end, through WC towards the surface (Figs. 7-10). Figure 11 is a composite photograph that pieces together the 12-line west section, constructing a single section but excavated in separate years and depicted on disparate profile drawings. In this way, we can follow the strata, as designated in the clearer, undisturbed B11 to B12 southern section, through the disturbance. By inspecting several such composite photographs, stratigraphic decisions made by the 1992 and 1993 profile illustrators became apparent, as did the logic underlying those decisions, based on the information each illustrator had at the time.

To summarize: the two profiles pertinent to this area of the western block disagree in major ways, and must be resolved. If the stratigraphic hypotheses on the clearer, undisturbed B11, B12 south wall and the profile drawings derived from that wall, the disagreements can be resolved in a way that coincides with the evidence from the west sections. To do the opposite--basing hypotheses on the disturbed south wall of C12-- we would need to somehow resolve the resultant sequence with the evidence of the more clearly stratified B12 south wall. Because this is, in fact, impossible, the better solution is unmistakable.

RESULTS - STRATIGRAPHIC DESCRIPTIONS

The tables which follow give general descriptions of the Die Kelders stratigraphy and master sequence, as reconstructed by this analysis. The appendix lists the stratigraphic units included in each level, by square.

The exact nature of the stratigraphic relationship between the eastern block material and the western block material is uncertain. This presents a problem for naming strata in a manner which is clear but does not imply anything about the nature of the relationship between the two blocks. For this reason, names for all strata from the western block begin with a 'W,' while names for eastern block strata begin with an 'E.' If the relationship between excavations is ever clarified, these labels can be combined into a single sequence without causing redundancy and confusion.

Western block

The western block deposits are numerous and complex, and contain the problematic combustion feature described above. Table 1 gives the level names, descriptions and basic stratigraphic relationships. As will be seen, we were often forced to aggregate levels within this block because of the difficulty of separating or identifying certain deposits across space, in all areas where such might appear.

Table 1: Western block stratigraphic levels and descriptions

Level	Description
WH	a midden with burnt material, including small pieces of charcoal. Level WH is thought to represent an individual fireplace, consisting of a shell lens overlying ash, with burnt organic material (mostly shell) and white ash patches within the larger ash body. This level, present in the southerly portions of the 9 and 10 lines, is not depicted in any of the figures.
WI	a clayey orange-brown lens, which apparently lies conformably under WH and over WJ. Contains domestic sheep.
WJ	a complex of thin, ashy, red and brown lenses. One small hearth appeared to be present in this level, situated in the NE quadrant of AA10. This level contained articulated tortoise, fish and *Raphicerus* sp. remains, and relatively few shells. Roots were common in this level. The excavators noted the similarity of this level to the so-called 'brown soils' at Nelson Bay Cave (Klein 1972).
WK	underlying WJ, consists of finely comminuted, decalcified midden deposit. Wads of estuarine eelgrass (*Zostera capensis)* were noted. Level WK overlies Level WM.
WA	a brown shelly matrix with a notable amount of bone and stone, occurring just under the surface in the 13 line and continuing westward to an unknown extent.
WB	consists of loose, fragmented shell and brown or ashy yellow matrix. WB underlies WA and overlies a mixed deposit described below (see Level WF)
WC	a thin, dark, shelly midden deposit underlying the surface in the southerly portions of the 12 and 13 lines. The sediment is medium to dark brown and contains large amounts of compacted shell and archaeological material.
WD	includes white ash containing charcoal and shell mixed with brown or pinkish sediment. The shell is a mix of whole and fragmentary specimens. Level WD underlies WC, but Levels WD and WC become difficult to distinguish to the north and west, and for most of their extent are designated WC/WD.
WE	consists of orange and brown midden material with whole and fragmented shell. Traveling to the north, WE becomes difficult to distinguish from underlying WF, described below. These two levels must often be lumped as level WE / WF.

WF	a dark reddish-brown sediment with copious shell, much of it whole. Some ash is also mixed in. WF peaks at the surface, but slopes downward to the west, under WE and WC.
WG	a brown or brown-yellow sediment with whole and fragmented shell, but a greater proportion is fragmented than is the case in WF. At least one small ash lens is present. WG underlies WF.
WL	an ashy midden appearing in the 12 line, under Level WG and over a stratum of mixed Levels WM and WN, described below. Fragmented shell is very common, and the excavators also noted the presence of a relatively large amount of charcoal and bone, as well as *Zostera* wads.
WM	finely comminuted midden containing some ash. Level WM underlies level WK and WG.
WN	a yellow sandy lens underlying Level WM. This level bore little archaeological material.
WO	a rich midden deposit underlying Level WN. This is a spatially extensive level which begins as a thin, lenticular deposit in the north east, and becomes thicker and merges with WQ to the south and west. Contents of WO included shell fragments, whole shell, bones, scrapers made from the shell of the white sand mussel, *Donax serra*, and charcoal. The distribution of material is discontinuous, so some areas are less dense with archaeological materials than others are.
WP	a white and grey ash deposit wedging in between Level WO and Level WQ (below), until it pinches out almost at the west wall of the 11 line. Shell and bone are sparse, but excavators noted a small group of articulated gannet (*Morus capensis)* bones.
WQ	A major, extensive deposit in the western group. A rich midden deposit in a loose, sandy matrix, this level underlies Levels WP and WO, but merges with WO as it dips to the west of the 10-line. Levels WO and WQ are largely indistinguishable throughout most of the excavated deposits. For this reason, it is difficult to know if the large deposit called mixed WO/WQ is generally mixed or is instead comprised predominantly of deposits from one or the other level. Given the richness and thickness of Level WQ, it seems most likely that this level predominates in the mixed deposit, but this supposition cannot be tested at this time. Articulated gannet remains were again noted in this level, as was the presence of whole mussel shells.
WR	underlies Level WQ. Level WR is a midden complex that also dips steeply towards the west. In places, level WR contains a large amount of ash, but shells within are unburnt and often whole. Some stratigraphically contemporaneous ashy deposits interfinger with level WR, particularly in the area of square B11 (see WS and WT, below).
WS	loose midden material with a relatively large amount of ash, although the shells within are unburned. Excavators noted the presence of rootlets and charcoal. Shell in this level is a mix of whole and fragmented material. Level WS appears to be divisible into upper and lower middens in B11, but this distinction is not visible elsewhere. Level WS underlies level WR, but WR and WS merge to the west and north (11-13 lines), becoming Level WR/WS. Level WS itself merges with WT in the 12 and 13 lines, where it is re-named WS/WT.
WT	another major unit in the western excavation area. This unit begins as a loose midden with a weakly lenticular structure in the southeastern squares, e.g. A9, A10, and AA10. This structure fades to the north and west, as the WT midden deepens and dips. As it deepens, archaeological material becomes less dense per unit volume relative to volume of sediment. Seeds were recovered in C10, and charcoal was quite common. Level WT underlies level WS.
WU	only present in the 10 line and eastern 11 line, WU is a compact ash wedge, below WT. The color varies from white to dark grey.
WV	another rich midden deposit of loose shell and bone. Underlies WU. Matrix is dark brown orange, with fine ash lenses within. This level tends to contain a relatively large amount of bone, sometimes in concentrated piles. Other distinctive finds included the rim from an ostrich-eggshell flask, *Zostera* wads and a concentration of cobbles. Shell appears to become more fragmented towards the bottom of this level, which is divisible into two sub-units in B10, but not in any other squares.
WW, WX	are present only in A10, AA10 and A9. They are lenticular ash lenses, similar in character and extent. WW overlies WX and is greyer in color, whereas WX is more reddish-similar to the matrix of the underlying level WY2. These lenses appear to have little shell and bone.
WY	underlies WX, and is a thick, extensive midden deposit with weak, discontinuous internal structure-lenses that form and peter out in less than a meter. It tends to be loose in texture and

	rich in faunal material, with brown matrix crossed by ephemeral, ashy lenses. In places, the matrix has a distinctly granular texture. Seeds and *Zostera* patches were also recovered, from square C10 and B12, respectively. Level WY is partially divisible into four sub-units in the 10 and, possibly, 11 lines. Of the four sub-units, WY2 appears most extensive.
Schweitzer's Layer 12	a dark maroon, organic-rich layer identified by Schweitzer in the 1970's excavations, this level is easily identifiable by its distinctive color. Avery and colleagues' (1997) excavations retained the designation 'Layer 12,' although they were able to subdivide it into 12i and 12ii in some places. Here, we seek to retain the common reference and avoid confusion by calling this level "Schweitzer's Layer 12." Schweitzer's layer 12 seems to have contained multiple hearth features, as well as fire-shattered rock, carbonized wood and seeds, along with large amounts of bone. This level pinched out to the north and west, and was not present in all squares. Perlemoen (*Haliotis midae*, also known as abalone) shells commonly appear at the base of Schweitzer's 12, especially in the western area, and these disappeared along with the distinctive stratum.

Additional comments on the Western Block strata

Levels WH, WI, WJ, WK

Levels WH, WI, WJ and WK (hereafter, WH- WK) occur only in the southeast portion of this block of excavations-in squares BB9, BB10, AA9, AA10, A9, A10 and B10 (not all of these levels are present in each square). They may represent short-term occupations, based on their depth and contents, although there is no way to know the character of these strata in the large, unexcavated area to the south of these squares. Restricted to the southeastern squares and overlying Level WM, which does not extend into the 13 line, there is no direct stratigraphic link between the two sets of uppermost deposits (WG-WC and WH-WK) and it is not possible to discern the exact nature of their stratigraphic relationships to one another. Given the results of ^{14}C dating discussed below (Table 4), it seems likely that WH-WK are the most recent deposits, post-dating levels WG-WC. Level WL and Level WK both lie upon Level WM, and so are most likely to be contemporary. The WH, WI, WJ and WK Levels are thinner deposits than WA-G, and their contents (discrete hearths, *Raphicerus* sp. skeletal elements in spatial association) suggest that these layers may have formed over a relatively short span of time, but there is currently no way to test this speculation.

Mixed deposits of WC/WD and WE/WF underlie WA in the 13 line. From the evidence at hand, we cannot be sure which of the levels WC, WD, WE, or WF are or are not present in that mixture, which tails off at an erosion feature. WA and WB appear to the north of that feature and the interface is nonconformable. WA and WB may be contemporary to WE, WD and/or WC, or they may represent later depositional events, once overlying the tailing off mixture of WE, WD, WC

Level WT

Level WT can be separated into two to three sub-units in B10, B11, C11, and D11, as noted in the appendix. These subunits cannot be traced in the remaining squares, even in squares outside the burned area, such as A10. We believe the sub-units may be individual shell dumps within the larger level. They were not assigned separate level names due to a combination of small spatial extent and relatively indistinct borders.

In the severely burned area, the shell in WT becomes highly fragmented and burned, as is the case for other middens in the burned region. This burning and fragmentation homogenized the deposits, so that it is very difficult or impossible to differentiate some of the individual deposits, even when these were easily separable in the eastern squares- along the 9 and 10 lines, for instance. In this case, Level WT becomes Level WS/WT, as discussed above.

WS/WT may be mostly comprised of one or the other deposit, but again, this cannot be tested at present.

Level WV

The western extent of Level WV appears to terminate abruptly in the 12 line, as seen in the B12 south wall. (see Figures 7 and 8). The extreme vertical nature of this termination suggests some disturbance, which makes it difficult to trace whether the deposit truly terminates or perhaps merges or dissipates into other levels, either WY or mixed WR/WS/WT. We believe that the deposit represented by Level WV terminates before the 12 line-hence, Level WV is not present in level WR/WS/WT, and is not present west of the 12 line.

Eastern block

LSA strata in the eastern block of excavations are less numerous than for the Western block. Marean and Lenardi's unpublished notes are paraphrased and their interpretations presented below.

The eastern block excavations abut the cave wall, and the excavators often noted that the character of a stratigraphic unit changed as it approached the cave wall. As a general rule, the notes observe that sediments abutting the wall are looser, with shell more complete than further from the wall. Table 2 presents the level names, descriptions and basic stratigraphic relationships.

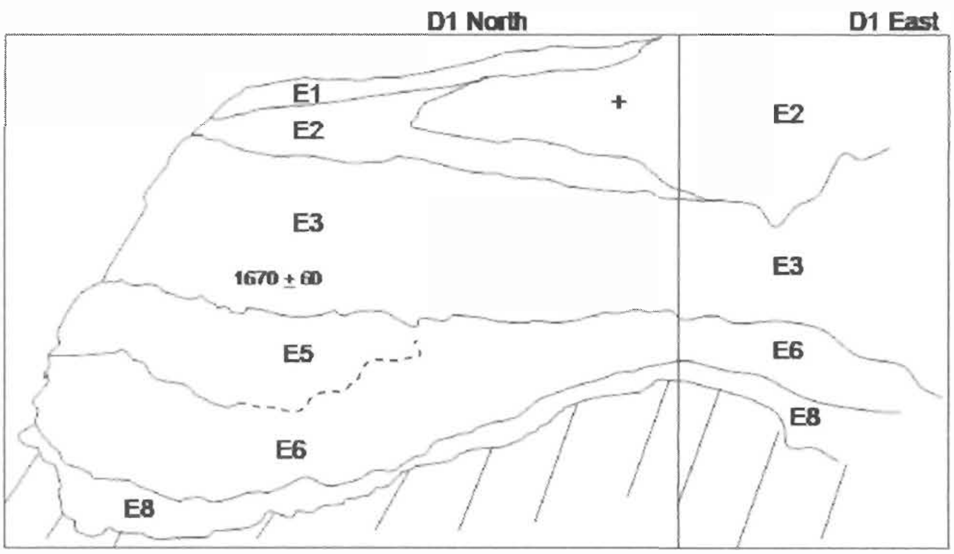


Figure 15: Diagram of D1 North and East profiles. Eastern block photos were taken by Mike Lenardi and Curtis Marean.

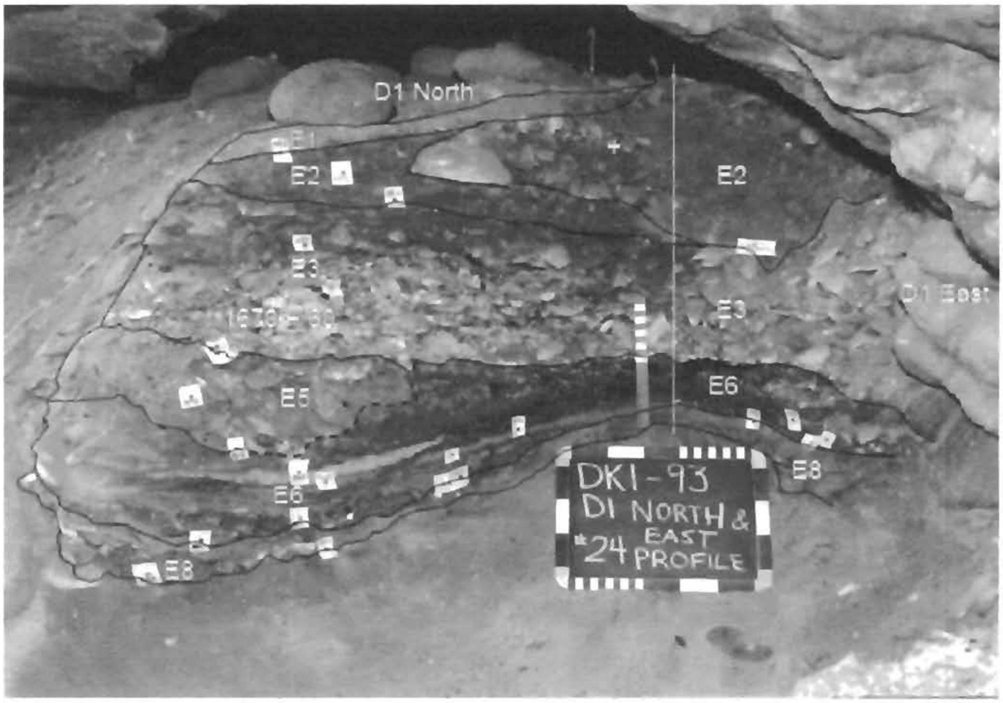


Figure 16: D1 North and East photograph

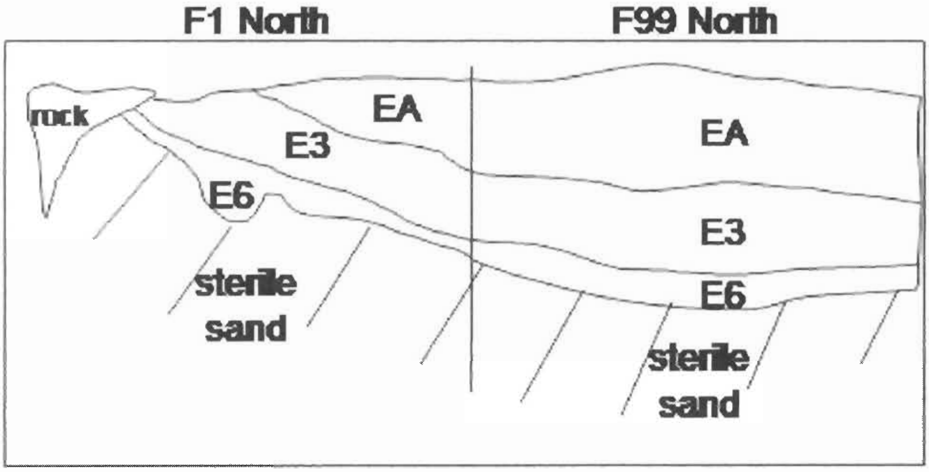


Figure 17: Diagram of F1 and F99 North profiles

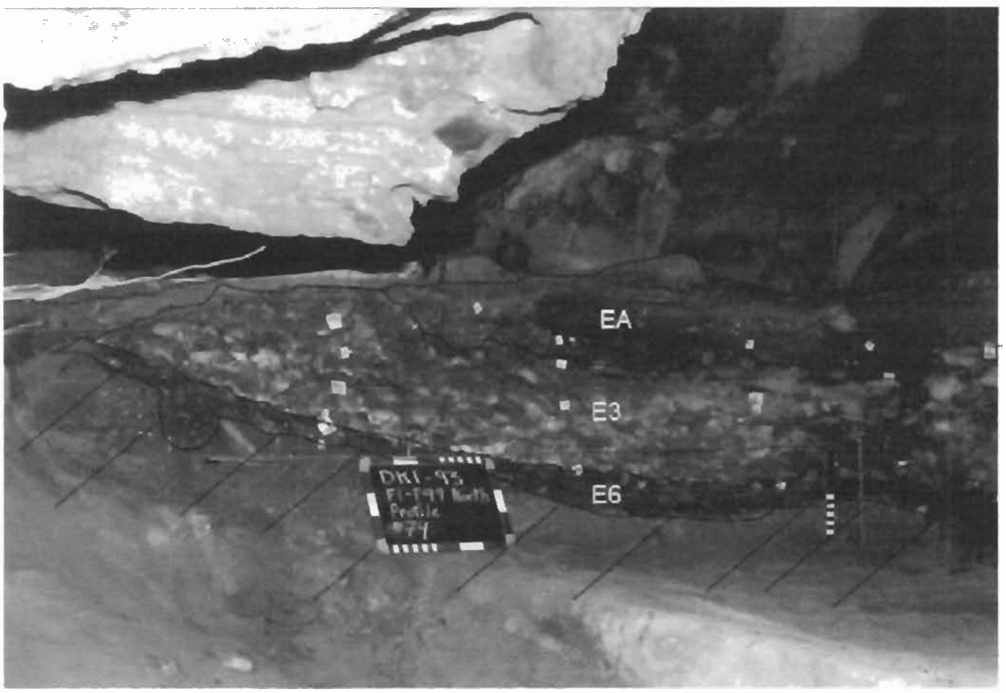


Figure 18: F1 and F99 North profile photograph

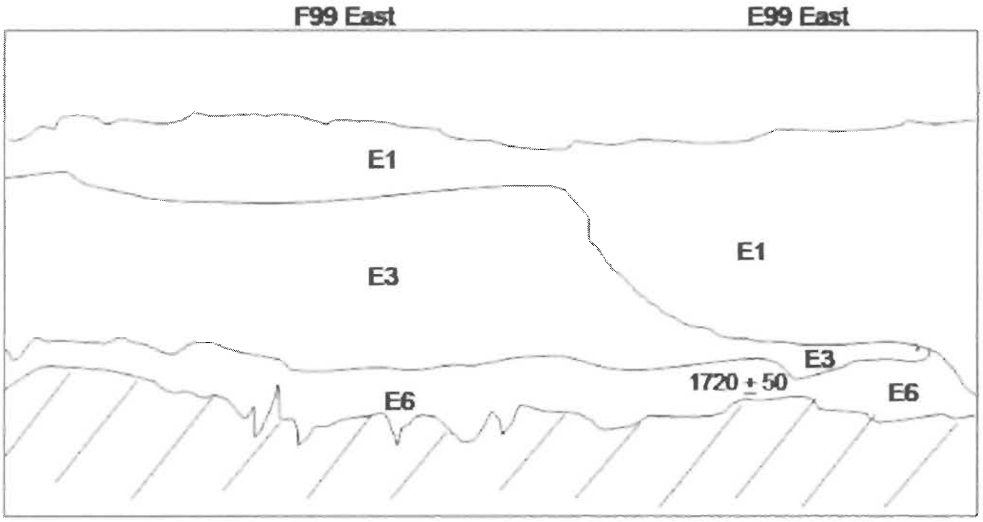


Figure 19: Diagram of F99 and E99 East profiles

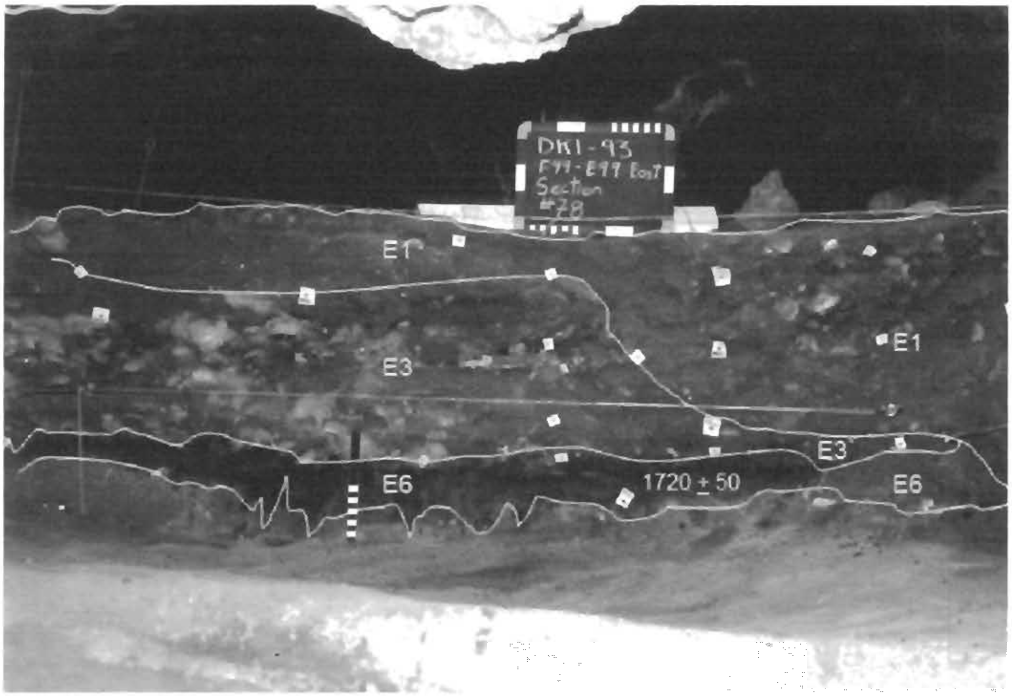


Figure 20: F99 and E99 East profile photograph

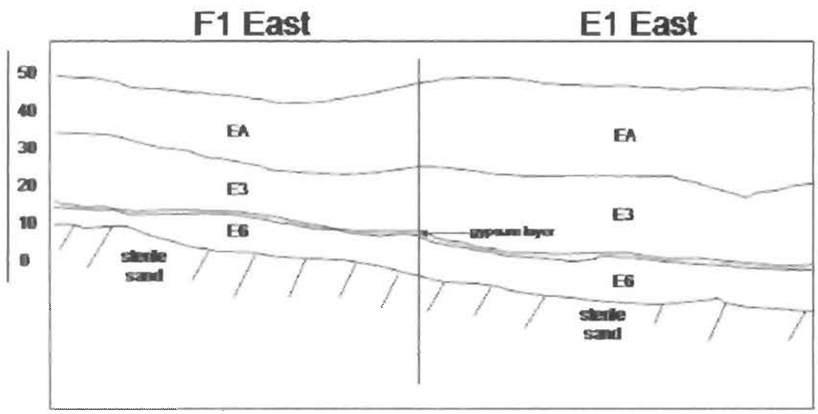


Figure 21: Diagram of F1 and E1 East profiles. There is no accompanying photograph for this diagram.

Table 2: Eastern block stratigraphic levels and their descriptions

Level	Schweitzer's Unit	Description
E1	Unnamed thin lense	a light to medium brown, sandy and loose sediment. This is a thin deposit, probably disturbed. Marean and Lenardi (unpublished notes) believe it equivalent to a thin, unnamed surficial lens illustrated on Schweitzer's (1979) published east section.
E2	Layer 2	loose, shelly and sandy brown midden incorporating probable hearth lenses. Bones and seeds very commonly exhibited rodent gnawing. Fish, tortoise, and bovid remains are present. E2 underlies disturbed surface material or E1.
E3	Layer 3	another brown midden deposit, considerably denser in shell than the overlying Level E2, and topped by a compacted sediment crust in some places. Shell in this level lay mostly horizontally and was not much fragmented. Archaeofaunal remains were particularly abundant, and at least one patch of sediment contained a fair amount of highly fragmented charcoal. E3 underlies E2 and EA. It appears broadly congruent with another level, EB, described below.
E4	Pitfill Midden A	a midden level, the shell highly fragmented and strongly dominated by mussel. The excavators noted an abundance of fish and small mammal bone in this thin horizon, which is not pictured here, but where present, underlies E3.
E5	Ashy Soil Lense	a loose brown sand horizon. The upper portion (unit MMO) contains few organic remains, but of those, several appear to be the associated remains of individualswe. Marean and Lenardi noted the commonness of lithic artifacts, including hammerstones, in this upper unit. The lower stratigraphic unit within E5 (MMQ) was more dense with shell than the upper units (MMO), including some complete specimens. E5 underlies E4.
E7	Soil Unit C	a small body, comprised of a single stratigraphic unit (MMU), and not pictured here. E7 is a sandy midden deposit, colored grey from its ash content. The excavators noted a high frequency of lithics, again including hammerstones. Archaeofaunal remains were common. Much of the shell was mussel and perlemoen.
E8	Pitfill Midden B	is topped by a thin, dark, nearly sterile, sandy lens unit (MMZ) with scattered lithics, ochre and seal bones. Below this lens, organic-rich midden material occurs, also in dark matrix. These succeeding deposits are rich in shell and other archaeofaunal remains, as well as ochre. The bottom of this level *may* be equivalent to Schweitzer's Layer 12, which does not appear in the eastern block.
EA	Unnamed thin lense and Layer 2[†]	a surficial level, EA is named differently from the previously described units because it is intercalated with or diffuses into the other uppermost levels (E1, E2, E3), making the precise relationship unclear. EA may even be a disturbed portion of all these. It appears as a loose brown sandy deposit containing largely complete mussel shell. EA is underlain by EB.
EB	Layer 2, Layer 3 and Pitfill Midden A[†]	consists of a single stratigraphic unit, MMK. This unit underlies EA and inter-fingers with E3, underlying a stratigraphic unit (MMI) near the top of that deposit. This suggests that EB is broadly contemporary with E3, but we have given it a separate designation because Marean and Lenardi (unpublished notes) observe its similarity to EA and because of the difficulty of separating those two in some areas. They suggest the possibility that EA and EB really are one body or are homogenized through disturbance, not uncommon in deposits abutting cave walls

[†] These correlations are tentative.

Additional comments on the Eastern Block strata

The uppermost unit (MMP) of Level E6 was a dark deposit which the excavators described as 'rusty-brown,' and 'humic,' in sharp contrast to the overlying E5. This description draws a strong parallel with Schweitzer's layer 12, which is a dark, organic-rich, and shell-poor level, in contrast to Die Kelders' more usual midden deposits, which tend to be either shell-rich or else are sandy or ashy deposits with little shell but also lacking the organic-derived resemblance to humus. Sterile sandy lenses (units MNC, MMV, MMW and MMX, from top to bottom) underlay the uppermost unit within the larger E6 deposit. MMW in particular, contained some charcoal and rare shell, while the remaining units were, for the most part, sterile. The sandy, primarily sterile units were distinguished by color--brown, yellow, brown/grey, and white/orange, respectively.

Dating

The Die Kelders deposits were originally dated by Schweitzer (1979). Table 3 gives the range of radiocarbon dates obtained from material he excavated. From dates he obtained on charcoal, it appears that the deposits he excavated can be bracketed between roughly 2000 and 1400 years bp. More recently, sheep remains from the site were found to date roughly between 1200 and 1300 bp (Sealy and Yates 1994).

Table 3: Radiocarbon dates from the 1969-1973 excavations. AMS dates on sheep bone are from Sealy and Yates(1994 Table 2). The remainder are conventional dates from Schweitzer (1979: Table 1).

SCHWEITZER'S LAYER	LAB NUMBER	^{14}C YEARS BP (5730-YEAR HALF LIFE)
2	GX-1685	1509 ± 100
2	GaK-3955	1648 ± 120
2	GaK-3877*	1699 ± 90
2	GaK-3878*	2699 ± 100
3	GaK-3956	1638 ± 80
4	GX-1686	2080 ± 95
4	UW-291*	1524 ± 55
7	OxA-3860†	1325 ± 60
7	OxA-3861†	1290 ± 60
7/9	GX-1687	2019 ± 95
12	GX-1688	2019 ± 85‡

* These samples were washed before collection; Schweitzer considered them to be less reliable.

† AMS on sheep bone

We dated samples from the later excavations in order to address a number of problems. First, since the earlier and more recent excavations necessarily sampled different deposits, it was important to establish an absolute chronology for the more recently excavated material. In addition, the direct dates from sheep remains and the dates of the matrix from which they originated were incongruent (Sealy and Yates 1994). This left some confusion surrounding the accuracy of Schweitzer's ^{14}C results, and highlighted the need for an independent chronology. Lastly, since the large combustion feature represents a major post-depositional disturbance, and since it has proven difficult to determine how individual stratigraphic units were affected by that disturbance, we wanted to learn how the unburned material to the north and west of the feature fit into the chronology of the unburned deposits south and east of it.

Table 4 presents the samples submitted from material recovered during the 1992 and 1993 excavation. Broadly speaking, our dates are not incongruent with Schweitzer's dates. The deposits appear to date between roughly 2000 and 1100 years bp. Level WJ, as expected, is the youngest sampled deposit. The small deposits overlying WJ are similar in character and likely date to the same time frame. The next two dates, deriving from Level WE/WF in C12 (Figures 9 and 10) and WQ/WS in D11 (from Southeast quadrant of D11 - not pictured but approximate location given in Figures 5 and 6 in western C/D 11), provide dates that are the reverse of what is expected, given their relative stratigraphic positions. At one standard deviation the dates overlap, so we do not consider this reversal to be a serious problem.

In C11, on Level lower WT, we obtained a surprisingly old date of 1960 $\pm$ 80. WT was divided into upper and lower portions because of the depth of the deposit and because, although it appears to be made up of two distinct units, the borders of these units are not distinct, and the separation remains tentative. The date does not confirm or deny the possibility of separable depositional events in WT, but WT must be either a long palimpsest unit or a series of deposits. As expected the sample from WY4 (the lowermost sub-unit of Level WY) is relatively old: 1900 $\pm$70 bp.

The two samples from E13 (Figures 13 and 14) were submitted in order to sample the compacted deposits to the northwest of the combustion feature. That feature homogenized the appearance and texture of the deposits within it, making it difficult to tell which stratigraphic units, present on one end, continued through the feature and were present on the opposite end. The angle and slope of shell within the feature suggest that a substantial degree of slumping or compaction took place within the burned region, so that the deposits to the northwest are thinner than those to the southeast. The results provide dates that are in correct stratigraphic order. It is interesting to note that they are on the older end of the Die Kelders occupation range, but it is also clear that the disturbance makes it very difficult to pinpoint which deposits are truly present, not to mention the difficulty of knowing which deposits were the ones yielding the dated samples.

Finally, two samples were dated from the eastern excavation block. We attempted to bracket the occupation in this area, although appropriate samples were unfortunately not available for the lowest units, E7 and E8, or for the uppermost units, E1 and E2. The dates from these samples correspond with their stratigraphic positions. Marean and Lenardi suggested (unpublished notes) that our E2 may be equivalent to Schweitzer's Layer 2, where the majority of sheep remains were found. Indeed, Level E2 also contained a large proportion of sheep remains (Frey, personal observation). For this reason, it is most unfortunate that we were unable to obtain a date for this level.

To summarize, the new set of radiocarbon dates confirms and extends the period of occupation attested by Schweitzer's radiocarbon dates. The deposits encountered in the later excavations include some that are more recent (WJ sample GX-31745 and overlying levels) than previously encountered. They also encountered deposits in the eastern block which are older than Schweitzer uncovered in that area (sample GX-31744).

Samples from the mixed/disturbed levels confirm that considerable slumping took place in connection with the large combustion feature (WQ/upper WT/WV, sample GX - 31747). There are not enough samples from the outer edges of the combustion feature to explain just how that feature affected deposits within it. However, we suggest that both slumping and compression took place. The lower, older deposits may have fared better, and may predominate in regions where considerable combustion and compression have taken place. Taken together, samples GX-31740, 31741, 31742, and 31747, for instance, illustrate this assertion.

Table 4: Radiocarbon dates from the 1992 and 1993 Later Stone Age excavations.

GEOCHRON SAMPLE NO.	SQUARE	LEVEL	FIGURE	STRATIGRAPHIC UNIT	MATERIAL	^{14}C DATE
GX-31745	AA10	WJ	not pictured	AAE	charcoal*	1100 ± 50
GX-31742	C12	WE/WF	11, 12	ACA	charcoal	1440 ± 50
GX-31747	D11	WQ/WS	5, 6	AATv	charcoal†	1370 ± 60
GX-31746	C11	(lower) WT	9, 10	AAWi	charcoal‡	1960 ± 80
GX-31740	E13	WL/WQ/WT/WY	13, 14	ACBi	charcoal*	1700 ± 60
GX-31741	E13	WL/WQ/WT/WY	13, 14	ADR	charcoal‡	1980 ± 80
GX-31739	B10	WY4	3, 4	ABG	charcoal	1900 ± 70
GX-31743	D1	E3	15, 16	MMJ	charcoal	1670 ± 60
GX-31744	E99	E6	19, 20	MMW	charcoal*	1720 ± 50

† There is a slight possibility that this sample underwent secondary (post-depositional) burning.
* These samples were not collected expressly for radiocarbon dating. Consequently, they may have been washed in freshwater.
‡ Due to the small size of these samples, they were submitted to extended counting time.

The new dates and early sheep in the Cape

For many years, Die Kelders provided the strongest evidence for the introduction of domestic sheep in the southern and southwestern Cape region, because sheep remains were found in layers dated 1960 ± 95 b.p. (Schweitzer and Scott 1973; Schweitzer 1979). The association between the sheep remains and the dated material has since been questioned, since direct dates on some of the sheep remains revealed them to be much younger (1325±60 and 1290±60 b.p.) than the dates from associated charcoal (Sealy and Yates 1994). Sealy and Yates compared the stratigraphic location of the remains to Schweitzer's profile drawings, noting that the early sheep came from very near a truncation feature in younger strata. The proximity of the specimens to this feature suggest that the so-called 'early' sheep remains could have been intrusive, having migrated downward from younger, overlying levels (Sealy and Yates 1994: 61).

The route and timing of the introduction of domestic stock remains controversial (Bousman 1998, Ehert 1982, Elphick 1977, Henshilwood 1996, Sadr 1998, Sealy and Yates 1994, Smith 1998). Other direct-dating efforts have shown that several other sites in the region experience the same phenomenon, with the earliest sheep remains yielding dates much more recent than the deposits from which they originate (Sealy and Yates 1994; 1996). On the other hand, at Blombos Cave, Henshilwood (1996) recovered and dated two specimens of domestic sheep remains which yielded dates that were both early (1960±50 and 1880±55), and consistent with dates on charcoal and marine shell from the associated deposits (e.g. 1840±50, 1900±40). Similarly, at the site of Spoegrivier in the Northern Cape (Webley 1992), direct-dating of the earliest diagnostic sheep remains yielded a date of 2105±65 b.p. (Sealy and Yates 1996:62). Other sites with purported early sheep suffered a fate similar to that of the discredited Die Kelders sheep (Inskeep 1987; Sealy and Yates 1994, 1996). At Nelson Bay Cave for instance, direct dates on sheep remains changed the earliest-occurrence dates from 1930 ±60 b.p. to 1100±80 b.p. (Inskeep 1987), a dramatic shift (see Bousman 1998, Henshilwood 1996 and Sealy and Yates 1994 for comprehensive reviews).

We have not directly dated any sheep remains at this time, as dating the introduction of sheep was not our purpose and a detailed discussion of the Die Kelders archaeofauna is beyond the scope of this paper. However, we will briefly outline the relevance of these new dates to the discussion of the early sheep at Die Kelders. Archaeofaunal data are from Frey, unpublished data.

Sealy and Yates (1994) observed that most sites alleged to contain sheep remains pre-dating c. 1600 bp yielded very small numbers of diagnostic sheep remains from the pre-1600 bp levels, with much larger numbers from levels post-dating c.1600 bp. This was the case at Die Kelders, as well as at Kasteelberg, Spoegrivier and /Ai tomas. The more recent Die Kelders excavations corroborate their argument. Here, the largest numbers of sheep remains coming from higher levels: E3 and E2, for instance (Frey, unpub.).

A detailed examination of the levels from which samples were dated highlights the importance of considering the context of the dated samples and the archaeofaunal remains. We begin with the Western excavation block.

None of the dated samples were directly associated with sheep remains. Lacking such a direct link, we turn to stratigraphic connections. Unit AAE, in Level WJ is the only *stratigraphic unit* in the western block from which both dated charcoal and diagnostic sheep remains were obtained. The age of this level and associated sheep, as well as those from levels WE/WF and WQ/WS are uncontroversial, having provided dates firmly younger than 1600 bp.

Two dated charcoal samples derive from Level WL/WQ/WT/WY, the shallow, possibly mixed deposits just north of the massive combustion feature. Our knowledge of the deposits contributing to this level is very incomplete; we would not link these dates with sheep remains from any of the potentially contributing levels: WL, WQ, WT or WY.

This brings us to two last dates from the western block- the first from Unit AAWi in lower WT, and the second from ABG in Level WY4 , the lowest subunit of WY. Although neither stratigraphic unit contained sheep, both levels yielded a very small number of sheep remains, but all from within the combustion feature. The dated charcoal did not come from the burned area. We have already suggested that these burned regions may subsequently have experienced substantial compression. Homogenized, burned deposits make it exceptionally difficult to trace stratigraphic units through this feature. Under these circumstances, connections between these remains and the dates are tenuous.

Turning to the eastern block, the two remaining dates do not dispute the Sealy and Yates argument. The preponderance of sheep remains derive from E3 and E2. By association with our single charcoal sample from E3, it appears that this level accumulated sometime around 1600 or 1700 b.p, with E2 an unknown younger age. Few, if any remains derive from underlying levels, including E6. Level EB, comprised only of unit MMK, did contain sheep, but it is impossible to say which other levels might be the contemporaries of MMK, and so MMK remains untethered and undated.

In conclusion, the new dates from Die Kelders do little to elucidate the timing of the earliest sheep in the Cape. A small number of remains derive from contexts that may pre-date 1600 b.p, but none are from unassailable contexts, and the association between the remains and the dated samples is indirect, the samples having been chosen for their potential to contribute to the chronology of deposition, rather than the chronology of stock-keeping. Resolution of this issue awaits additional accelerator dates on the sheep remains themselves. In the meantime, analysts should consider the integrity of the Die Kelders deposits carefully when conducting analyses which are sensitive to change over time. If a secure chronology is crucial, deposits from within the burned area, and deposits which are unburned but separated from others by the burnt region, may need to be excluded from analysis.

CONCLUSIONS

Die Kelders cave is a remarkable site, containing deeply stratified deposits from both the end of the LSA and from the MSA. First excavated by Schweitzer in the 1960's and 1970's, the cave was excavated again in the 1990's, but the stratigraphy of the LSA deposits from that excavation remained analyzed.

We provide that analysis here, along with a master stratigraphic sequence for Die Kelders based upon careful examination of excavation notes, section photographs, section drawings, and discussions with excavators. We also report the results of nine radiocarbon dates in order to provide a chronological framework for the recently excavated deposits and to clarify the relationship between the deposits excavated in the 1970's and those excavated in the 1990's.

As one of only two large and deeply stratified post-pastoralist occupations yet excavated in the Western Cape, the Die Kelders material is crucial to understanding pastoralism in South Africa. It is our hope that the detailed discussion of the Die Kelders stratigraphy we have presented here will allow others to include material from this remarkable site to investigate problems involving behavioral change over time. Moreover, we hope that our stratigraphic hypotheses are presented in such a way as to allow those investigators to appraise the Die Kelders stratigraphy themselves, both in order to adapt or modify our hypotheses as warranted, and to include in their analyses only those deposits which will allow them to answer their particular questions.

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Appendix 1 Western Excavation Area:

Squares A10, AA10, AA9 and A9: Stratum WH = AAA*, AAB*, AAC*; WI = AAD; WJ = AAE, AAEi, AAEii, AAEiii, AAF; WK = AAG, AAH; WM = AAI, AAJ; WN = AAL; WO = AAN, AAK, AAM*; WP = AAO, AAP, AAQ, AAQi; WQ = AAQiii, AAQiv; WR = AAR, AAT, AAS; WS = AATi AATii, AAU; WT = AATvi, AAV, AAW, AAX, AAVii, AATiv*, AAWiii*, WU = AAY, AAZ, AAZi, AAZii, AAZiii; WV = AAZiv, ABB, ABC, ABCi, ABCii, ABCiv, ABA; WW = ABCiii, ABCv, ABCvii, ABCvi; WV/WX = ABCiv; WX.1 = ABCviii, ABCx, WX.2 = ABCix; WY.1 = ABD, ABDi, ABE; WY.2 = ABEi, ABEii, ABEiii, ABF; WY.3 = ABEiii; WY.4 = ABG; 12i = 12i; 12ii = 12ii.

Squares B7, B9, B10, BB9, BB10: Stratum WH = AAA, AAB; WN = AAL; WO = AAN; WP1 = AAO, AAP, AAQii, AAQiii, AAQ, AAQv*, AAS in Eastern quads; WQ = AAQiv, AAR, AAQvi; WR = AAS in western quads, AAT, AAR; WS = AATi, AATii, AATiii, AAU; WT = AATv, AATiv, AAV, AAW, AAVi, AAWi, AAX; WU = AAY, AAZ; WV = ABA, ABB, ABC, ABCiii, ABCix; WY2 = ABCx, ABD, ABDi, ABE, ABEi; WY3 = ABEiii; WY4 = ABG, 12i = 12i; 12ii = 12ii. Strat units not pictured or described, consequently dropped from analysis: AATvi, ABEii.

Square C10[7] = WP1 = AAO, AAP, AAQv, AAQ, AAPi; WR = AAR, AAS; WS = AAU, AATi, AATii, AATiii; WT = AATv, AATvi, AAW, AAWi, AAWii, AAWiii; WU = AAY; WV = ABA, ABB; WY2 = ABE, ABD, ABEi, ABEiv, ABEv, ABEiii, ABEvi, ABG; 12 = 12; 12i = 12i; 12ii = 12ii. Strat units not pictured or described, consequently dropped from analysis: AAQvii.

Square D10: 12 = 12; 12i = 12i

Square B11 2nd: WC = AEJ; WF = AEK, AEKi, AEL; WG = AELi, AELii, AEM; WM = AEMi, AEQ, AES AEN; WN = AFE, AFS, AHV, AFB; WO = AFY, AFF, WP = AFZ; WQ = AGA; WR = {AGAi in eastern quad}, AGC, AGAiii, AIJ; WR/WS = {AGAii, AGC in western quad}, AIK; WS = {AGK, AGP and AGPi, in western quad}, AGE, AGL, AGM, AGMi, AGMii, AGQ, AGT, AIP, AIL; upper WT = {AGP AND AGPi in eastern quad}, AGX, AGV, AIQ; lower WT = AGXi, AGY; WU = AGZ, AGZi, {AHB in eastern quad}; WV = {AHB in western quad}, AHC, AIS, AGX in west; WY2 = AHD, AHDi, AHE, AHH, AHK, AHL, AHN, AHO; 12 = 12. (Disturbed Units Not Included: AEV, AEZ, AFX. Strat units not pictured or described, consequently dropped from analysis: AGB, AHI)

Square C11: WF/WE = ABI, ABH; WM = ABJ, ABJi; WO = AAN, AANi, ABI, AAWi, AAWiii, ABK; WP = AAPi, AAPii, AAQviii, AAQix, AAQxix, {AAQx, AAQxi, AAQiv in southeastern quadrant}; WQ = {AAQxi in northern and western quadrants}, AAQxii, ABKi, ABKii, ABKiii; AAQxv, AAQxvi, AAQxvii, AAQv, {AAQx in northern and western quadrants}, AAQxx, AAQxxi, AAQxxii, AAQxiv, ABJiii, ABJiv {AAQiv in western and northern quadrants}, {AATi in northern quadrants}; WQ2 = {AATi, AAQvii, AAQxvii in southwestern quadrant}; WS ={AATix in western quadrants}, AATviii, AAQxviii, AATv, {AATi in southeast}, {in northern and western quadrants AATx}; WS2 = AATvii; upper WT = {in southeastern quadrant AATix, AATx}, AATiii, AATxii, AATxxi, AATxx; lower WT = AATxiv, AATxiii, AAWiv; AAWi, AAWv; {in southeastern quad ABA}, {ABW in northern quads}; WU= {ABAi in southwestern quad}; WV = {ABAii in southwestern quad}, ABBi; WY = {ABA, ABAi, ABAii in northern and eastern quads}, ABC, ABCix, ABEi, ABG, ABT, ABU; 12 = 12; 12i = 12i; 12ii = 12ii.

Square D11: WQ/WS/WV = ABK, ABKiii, ABKi, AAQiv, ABKii, AAQxvi, AAQxvii, ABL, AATi, AAQxviii, AATv, AATvii, AATviii. AATix, ABLii, ABLiii; Lower WT = ABS, ABT; WY = ABU, ABV, ABW, 12 = 12. Strat unit not pictured or described, consequently dropped from analysis: ABH.

Square E11, F11: WQ/WS = ABV, ABLi, ABLii, ABLiii, ABLiv, ABLv*; WY = ABQ, ABW; 12 = 12. Strat units not pictured or described, consequently dropped from analysis: ABR.

Square B12: WC = AHA, AHE, AAEJ; WD = AHFi; WE = AHF, AHG; WF = AEL, AELi, AHP, AHJ, AHM, AEK, AEKi, {in western quadrants AHR, AHO*, AHIi}, {in northwestern quadrant AHT, AHU}; WG = AHS, AHQ, AELii, {in southern and eastern quadrants AHT, AHU}, {in northwestern quadrant AHY, AIA, AHUi}, WL = {in southern and eastern quadrants AHUi, AGA}, {in northwestern quadrant AIB, AIC, AICi, AID}; WN = {in northern and eastern quadrants AIB, AIC}, AHV, AHW, {in northwestern quadrant}; WO/WQ = AIS, AIE, AIEi, AIEii, AIEiii, AIEiv, AII, AHZ, AHX, AIF, AIG {in southern and eastern quadrants AGA}, WR = {in eastern quadrants AIGiii, AIH, AIJ}; WR/WS/WT = AGAi, AGAii, {in western quadrants AGAiii, AIH, AIJ} AIT, AIQ, AIX; WR/WS = AIK, AGM, AGL, AGMi, AJB, AJC, AJD, AIE, AIM, AIN, AIO, AIV, AIW, AIY; WS = AGPi, AGP, AIL, AIP, AIQ, AII, AGT; WT = AGV, AGX, AIR, AJR, AGV; WV = AGX, AHB, AHC, AIS; WY = AHDi, AHD, AHH, AHN, AIT, AJF; 12 = 12. Strat units not pictured or described, consequently dropped from analysis: AIGiii

Square C12: WC/WD = ABX, ABZ, ABZi; WF/WE = ACA, ACAi; WG = ACAii, ABI, ABIi; WL = ABJ; WO/WQ = ABJi, ABJii, ABJiii, ABJiv, AAQv, AAQx, AATi, AATvii; WS/WT = AAWv, ACC, ACCi, ACCii, ACCiii, ACCiv, AATxiii, AATx, AATxii, AATxx, AATix, ABExi, AATxxi, AATviii, ACCii; WY = ABA, ABBi, ABCix, ABEi, ABG, ABCxi, ABU, ABT; 12 = 12.

Square D12: WC/WD = ABZi, ABX; WF/WE/WG/WL = ACA, ACAi; ABJ; WO/WQ = ABJii, ABJiii, ABJiv, ABJi, ABK, ABKi, AAQv, AATi; WS/WT = AATviii, ACCii, ACCiii, AATix, AATx, AATxii, AATxiii; WY = ABG, ABGi, ABT, ABU, ABW, ABEi, ABWi, AFR, ABV; 12 = 12. Strat units not pictured or described, consequently dropped from analysis: ABI.

Square C13: WB = ADF; WD/WC = ABX, ABYi, ABXii, AEX, AFC; WE/WF = AFW, AGD, AGF, ABXi, ACA, AFG, AHUi, AFU*, AEH, ADI, ADM, AER; WG = AGB, ACAii, AHY, ADMi, AGE; WL = AIA, ABJ, ABJi, AGB, AGH, AGG, AGI, ADN*, ADY, AEC*, AED; WQ = AGJ, AIM, AGN, AGNi, AEG, AEE, AEGi, AGO, AEDi, AEE, {in eastern quads AGNii}; WR/WT/WS = {in western quads AGNii}, AJC, AGNiii; WY = AGU, AGW, AGY; 12 = 12. Strat units disturbed or not pictured or described, consequently dropped from analysis: AGSi and ADA, AGR, ACAi, AGS.

Square D13: WA = ADB, ADD, ADC, ABN, ADG; WB = ADF, ADL, ADM, ADJ; WF/WE/ WB = ADJ; ADJi, ADJii, WF/WE = ABZi, ADEi, ADMi, ADN, ACA, ACAi, ADMii*, ADO, ABMi, AGB, AFW, AEH, AER, AEW, ADH; WG = AGF, AGD, ACAii, ADH; WL = ABJ*, ADY, AEC*, AED, AEF, AFA, AFAi, AGG, AGI, ADD; WQ = AEDi, AEE, AEG, AEGi, AEO, AEP*, AET*, AEU*, AEW, AEY*, AFD*, AFJ*, AFK*, AFL*, AFA, AFH, AGO, AFM, AFW, AFI; WQ/ WS/WT: ADW*, AGNi, AGNii, AFM, AFN, AFO, AFP, AFQ, AEI, AFV, AFX; WY = AGW, AFR, AFS, AFT, AGU; X = ACB*; 12 = 12. Not pictured or sufficiently described, could not be placed = ADA, ADI, ADK, ADOi, AEA, AEB.

Square E12, F12: WB = ADJ; WD/WC = ABZ; WL/WF/WE = ABLi, ABN; WL/WN/WO = ABNi; WN/WO/WQ = ABM, ABL, ABMi, ABO, ABLii, ABLiii, ACB, ACBi, ABLiv; WQ/WR/WT/WS = ABLvi; WY = ABP, ABPi, ABQ, ABQi, ABQii; 12 = 12. Not pictured or sufficiently described, could not be placed = ABLv, ABC.

Square E13: X = ACB; WA = ADC, ADG, ABN, ADB; WB = ADJ; WL/WQ/WY = ACBi, ADR, ADRi, ADT*, ADU; WG/WF/WE/WD = ABMi, ADO, ADOi; WT = ABQ; WY = ABP, ABPi; Not pictured and location not described in notes, dropped for insufficient information = ADPi, ADP, ADJ, ADE.

Square F13, F14 = X = ACB, ACBi; Y2 = ADX; Y = ABPi; Z = ABQ.

Square F15: X = ADQ, ACB, ACBi; Y3 = ADV, ADT, ABV, ADS; Y2 = ADX; Y = ABPi; Z = ADZ, ABQ.

Appendix 2 Eastern Units:
Stratigraphic units pertain to all squares.

E1: MMB.
E2: MMF, MMD, MME, MMR, MMS, MMC, MMG.
E3: MMH, MMI, MMJ, MMM, MML.
E4: MMN.
E5: MMO, MMQ.
E6: MMP, MMV, MMW, MMX.
E7: MMU, MMUi.
E8: MMZ, MMY, MNA, MNAi.
EA: MMA.
EB: MMK.

*Position not resolved, the following units are removed from the stratigraphic reconstruction:
MNB, MNBi, MNG, MNH, MNI, MNK, MNM, MNN, MNO, MNP