A SYNTHESIS AND REVIEW OF
GEOMORPHIC SURFACES OF THE BOUNDARY ZONE
MT. TAYLOR TO LUCERO UPLIFT AREA
WEST-CENTRAL NEW MEXICO

SUBMITTED TO

DR. CHARLES HARRINGTON
LOS ALAMOS NATIONAL LABORATORY
ESS-1 MSD-462
P.O. BOX 1663
LOS ALAMOS, NEW MEXICO 87545

BY STEPHEN G. WELLS, CONSULTANT

NEOTEC, INC.
4045 SIMMS COURT SE
ALBUQUERQUE, NEW MEXICO 87131

JANUARY 1989

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
REPORT # 1
A SYNTHESIS AND REVIEW OF
GEOMORPHIC SURFACES OF THE BOUNDARY ZONE
MT. TAYLOR TO LUCERO UPLIFT AREA
WEST-CENTRAL NEW MEXICO

SUBMITTED TO

DR. CHARLES HARRINGTON
LOS ALAMOS NATIONAL LABORATORY
ESS-1 MSD-462
P.O. BOX 1663
LOS ALAMOS, NEW MEXICO 87545

BY STEPHEN G. WELLS, CONSULTANT

NEOTEC, INC.
4045 SIMMS COURT SE
ALBUQUERQUE, NEW MEXICO 87131

JANUARY 1989

DISCLAIMER
This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
INTRODUCTION

Purpose

The Mt. Taylor volcanic field and Lucero uplift of west-central New Mexico occur in a transitional-boundary zone between the tectonically active Basin and Range province (Rio Grande rift) and the less tectonically active Colorado plateau (Datil section) (Fig. 1). The general geomorphology and Cenozoic erosional history has been discussed primarily in terms of a qualitative, descriptive context and without the knowledge of lithospheric processes (e.g., Hunt, 1938, 1956; Bryan and McCann, 1938). The first discussion of geomorphic surfaces was by Bryan and McCann (1938) who suggested that the erosional surface underlying the Mt. Taylor volcanic rocks is correlative with the Ortiz surface of the Rio Grande rift. In 1978 Bachman and Mehnert supported this hypothesis with K-Ar dates on volcanic rocks within each physiographic province. The correlation of this surface was a first step in the regional analysis of the boundary zone; however, little work has been done to verify this correlation with numerical age dates and quantitatively reconstruct the surface for neotectonic purposes. Those geomorphic surfaces inset below and younger than the “Ortiz” surface have been studied by Wright during the 1940s and recently by Joel Grimm (former M.S. student) and Stephen G. Wells (e.g., Coleman et al., 1982; Grimm, 1985) from the University of New Mexico. This report provides a summary of these papers as well as unpublished data and a conceptual framework for future studies related to the LANL ISR project.
Regional Setting

The regional structural setting of the boundary zone is illustrated in Figure 2. The major relief-producing structural features include the Acoma sag, a strongly asymmetrical broad down warp of Mesozoic strata, and the Lucero uplift, a broad uplifted zone of Paleozoic and Mesozoic strata bounding the western flank of the rift. The McCartys syncline (or Mt. Taylor syncline; Hunt, 1956) is located along the axis of the Acoma sag. The major stratigraphic units exposed in the boundary zone are illustrated in Figure 3. Those units described as "pediment deposits" and "Quaternary alluvial and eolian deposits" will be described in detail within this report.

Three major landscape types dominate the study area:
1) broad alluvial valleys which are filled with Quaternary volcanic rocks and alluvium and are mantled by eolian deposits;
2) bedrock mesas which are capped by resistant Mesozoic sandstones or Cenozoic volcanic rocks and are flanked by barren cliffs and colluvial mantled slopes; and
3) pediment (erosional) surfaces which lie topographically between the mesa tops and valley floors and are mantled by veneers of gravelly alluvium. The regional base-level for this area is the Rio San Jose which drains eastward and transverse to the major structural elements (Fig. 2).
GEOMORPHIC SURFACES OF THE BOUNDARY ZONE

In this report a geomorphic surface is defined as a suite of landforms and genetically associated deposits that formed over a definable period of time and that can be related to a distinct period of base-level stability. Numerous authors have developed other criteria for determining a geomorphic surface (e.g., Gile et al., 1981); however, almost all criteria require evidence of landscape stability which is typically indicated by soil development.

Grimm (1985) has established that four geomorphic surfaces occur regionally throughout the Mt. Taylor area within the boundary zone (S1, S2, S3, and S4). The typical landscape/stratigraphic position of these surfaces and their deposits is illustrated in Figure 4. The oldest surface, S1, topographically lies several hundred meters above local base level; whereas, the remaining three surfaces typically occur less than 60 m above local base level. The surfaces can be recognized on the basis of surface gradient, slope orientation, degree of soil development, and relative height above local base level.

**Geomorphic Surface S1**

Surface S1 exists as remnants of a regional surface developed upon and truncating gently dipping Cretaceous rocks. The erosional basal surface, unconformity, is mantled by a sequence of Mio-Pliocene (?) sediments which in turn is overlain by the thick pile of the Tertiary Mt. Taylor volcanic rocks (Fig. 4). Little is known about the nature of this surface due to the limited exposure along the flanks of the mesas; however, the surface is best
preserved where it is capped by volcanic rocks. This surface is also known as the Ortiz surface of Bryan and McCann (1938) or the Mesa Chivato surface of Moench and Schlee (1967).

Exposures of the surface southeast of the Mt. Taylor area indicate a gentle slope toward the south with a gradient of 0.015 (Moench and Schlee, 1967; Grimm, 1985). Grimm (1985) suggested that this surface was graded to the ancestral Rio San Jose which was approximately 300 m above the present base level. Wright (1946) calculated that the stream systems developed upon the Ortiz surface proximal to the rift boundary had steeper gradients than the present drainage system. Wright, however, believed that the Ortiz surface should have lower gradients, and thus this surface has been tilted in response to subsidence proximal to the rift. The data for the western flank of Mt. Taylor and relatively distal to the rift boundary support Wright’s hypothesis for areas away from the rift. Modern channels have gradients on the order of 0.030 compared to the S1 surface gradient of 0.015. Extensive field work will be required to delineate the paleotopography of this surface and to assess the impact of local and regional deformation.

Thin-to-discontinuous, sandy to gravelly sediments rest unconformably on the slightly dipping Mesozoic strata and below the Mt. Taylor volcanic sequence. No thick alluvial deposits or soils have been observed on the S1 surface during preliminary field work. Grimm (1985) referred to the S1 sediments as unit Ta1 and determined that the deposits consist of approximately 90% sand and 10% gravel and mud matrix. The coarsest fraction of the sand and gravel is composed of quartz, quartzite, chert, and locally derived sandstones. Rounded-to-subrounded granitic clasts are locally observed, suggesting that the ancestral drainage system
developed on the S1 surface had access to Precambrian lithologies, such as those presently observed in the Zuni Mountains (Fig. 1).

It is possible that the thin deposits resting on the S1 surface in the boundary zone are correlative with the thicker deposits of the Tertiary Bidahochi Formation and Zuni surface, comprising the Zuni Plateau in western New Mexico and eastern Arizona (McCann, 1938; Cooley and Akers, 1961; Cooley et al., 1969; Wells, unpublished data) (Fig. 1). Approximately 4-3 Ma ago the Zuni Plateau was relatively undissected and was characterized by a low-relief plain developed over the top of the gravelly and sandy Bidahochi sediments (Wells, unpublished data). The upper member of the Bidahochi Formation (fluvial sediments) has been correlated with the Zuni surface by McCann (1938). If the Zuni surface is correlative with the S1 (Ortiz) surface in the boundary zone, then the thin deposits on surface S1 near Mt. Taylor may represent the zero edge of aggradation of the Bidahochi formation. This zero edge apparently occurred over a topographically higher (uplift?) area between the Lucero uplift and the Zuni Mountains (Fig. 1). Detailed field work will be required to establish these relations.

**Geomorphic Surface S2**

The landscapes of geomorphic surface 2 consists of pediments and alluvial fans inset within canyons developed below the S1 surface. Remnants of surface S1 typically lie 35 to 60 m above local base level; however, locally the remnants are only 6 to 20 m above local base level. The gradients of these surfaces, where measured, are typically 0.03 and are similar to the gradients of modern channels. The orientation of the S2 surface is typically concordant, but locally discordant, with modern
topography and regional slope. That is, the predominant slope orientation of the surface is down valley and parallel with the valley floor. Field observations suggest that changes in the direction of drainage systems developed on this surface occurred either by piracy, deformation, or a combination of processes. Grimm (1985) documented stream piracy as a major factor controlling the slope orientation of the S2 surface.

Approximately 5 to 10 m of sandy-and-gravelly alluvial-fan deposits occur locally on the pediment. Soil-profile development on this alluvium is characterized by a 40-cm thick Btk horizon with stage III pedogenic carbonate development (Table 1) (Grimm, 1985). Maximal B-horizon development is reddish-brown hue (5 YR), and the oxidized underlying parent material is very-pale brown (10 YR). The structure of the B horizon is angular blocky.

Geomorphic Surface S3

Surface S3 consists of pediment and alluvial fan surfaces which slope away from the side slopes of the mesas and merge down valley. The gradients of the S3 surfaces vary locally between 0.03 and 0.06. The surface changes down slope from pediments to alluvial fans which merge with the alluvial fill in the valleys (surface S4). Within the valley floor 0-5 m of relief exists between the valley floor and the top of the alluvial fan deposits; thus surfaces S3 and S4 are distinguished primarily on the basis of soil development within the valley floors.

The alluvial fan deposits are composed of sands and gravels derived from local sources (mesa flanks and older deposits of surfaces S1 and S2). The surface of the deposits are degraded, and are relatively less stable than
the S2 surface. Weakly developed soil profiles are typically found associated with the fan deposits (Table 1) (Grimm, 1985). Soil horizon development is characterized by > 20-cm thick cambic (Bwk) with 7.5 YR color and weak structure. Pedogenic carbonate accumulation is characterized by stage 1 development. It is possible the weak soil development may be a function of degradation of the surface and not the age of the underlying deposit.

Geomorphologic Surface S4

The valley floor of the canyons incised below the volcanic and sandstone-capped mesas represent surface S4. The valley floor is typically composed of a relatively thick fill of fine-grained sediments which are incised by discontinuous arroyos. The relief between the valley floor and the arroyo floor ranges between 0 and 10 m and decreases down valley. The gradient of the valley-floor surfaces varies between 0.025 to 0.009. The active channel within the arroyos have gradients from 0.20 in the headwaters to 0.03 in the middle canyon reaches to 0.01 in the distal reaches.

The sediments of the valley floor consist of alluvium (fine sands, silts, and clays with lenses of coarse gravel and sand) and eolian (sands and silt) deposits. Soil development on these deposits vary significantly. The alluvial deposits have a maximal profile development of A/C horizons, and the eolian deposits varies depending upon their age (units Qe 1, 2, and 3 of Table 1).

CONCLUSIONS
Possible Age Constraints on Surfaces

Volcanic rocks associated with Mt. Taylor range in age from approximately 4.3 to 2.4 Ma and rest upon the S1 surface. Basalts overlying Wheat Mountain (Fig. 5) cap a mesa that is 50-75 m lower than the flows associated with Mt. Taylor and is lower than the S1 surface (Moench and Schlee, 1967; Lipman and Mehnert, 1980). Grimm (1985), using three-point reconstructions, determined that the surfaces may be separated by as little as 11 m vertical relief and considered the pediment of Wheat Mountain to be part of surface S1. K-Ar dates on the flows of Wheat Mountain yield ages of approximately 2.4 Ma and within the range of ages of those volcanics of Mt. Taylor (Table 2). It is critical that the geomorphic position and geologic age of the S1 (Ortiz-Zuni?) surface be resolved because (1) the periods of surface formation, stabilization, and dissection may reflect tectonic processes related to lithospheric/asthenospheric interactions and (2) the surface may represent a regionally correlative "time line" across physiographic boundaries. Additional work is required in order to resolve questions of the amount of relief on the S1 surface, whether the surface is compound, and the age range of formation and stabilization.

Baldridge et al. (1987) have suggested that the "Ortiz surface" may be compound because flows of different ages (4.1 and 3.3 m.y.) rest on surfaces of different elevations (Mesa Lucero and Mesa de Oro, respectively). Older basalts (8.3 to 6.2 Ma) rest on higher surfaces along the crest of the Sierra Lucero. It is unclear whether these surfaces are genetically related to the S1 surface or may represent an older phase of regional base-level stability. Difficulty arises from the fact that the S1 surface is known to predate
volcanics of 4.3 Ma and could be as old as 8-6 Ma. Grimm (1985) suggested that the S1 surface of the Mt. Taylor area was probably established during the early Pliocene and may be as old as Miocene. This age range proposed by Grimm (1985) encompasses the age range determined by Baldridge and others for both the surfaces in the Lucero uplift.

Paleogeographic Reconstructions

The paleogeography of the Mt. Taylor and Lucero uplift areas of the boundary region may represent a broad uplifted region which was shedding sediments into basins both toward the east and west. The Rio Grande rift on the east was a rapidly subsiding and relatively narrow basin. Volcanic plugs dated at approximately 8 Ma intrude the basin fill sediment and are related to the flows that cap the top of Sierra Lucero (Baldridge et al., 1987). West of the boundary zones, sediment was shed into a very broad and shallow basin to form the Bidahochi Formation. Based upon vertebrate fossils in the upper member of the Bidahochi Formation, Lance (1954) and Reppening et al. (1958) assigned an age of middle Pliocene. Scarborough et al. (1974) and Evernden et al. (1964) provided K-Ar dates of 6.7 and 4.1 Ma for volcanics of the middle member. These dates overlap with the dates within the Mt. Taylor and Lucero uplift areas, suggesting that regional deposition on either side of the boundary zone was contemporaneous during the latest Miocene. Regional erosion and wide spread beveling of the rift/plateau boundary zone was ongoing during this time interval. A hypothesis is that broad upwarping of the boundary zone resulted in erosion and regional pedimentation which occurred over several million years in the Late Cenozoic. Approximately 3 Ma ago erosion and basin subsidence ceased to form a broad, relatively
stable surface of low relief which spanned from the Colorado Plateau, across the rift, and into the Great Plains. It was this surface upon which many of the volcanic flows, dating between 2 and 3 Ma, erupted (Fig. 6), apparently preserving the classic “Ortiz” surface.

Rapid incision after the formation of the Ortiz surface was proposed by Grimm (1983) and Wells (unpublished data). Minimum rates of incision on the order of 6 to 24 cm/1000 yrs have been estimated by Grimm (1983) for the Mt. Taylor area. The period of incision produced the major canyons observed throughout the boundary zone and marked the termination of the stable Ortiz surface. The period of incision may reflect a change in tectonic style across the region from broad, gentle upwarping to local, rapid uplift along the rift/plateau boundary.

All basaltic flows of the Zuni-Bandera and Bluewater fields, as well as some flows from the Lucero field, occur between the elevations of surface S2 and modern base level. A K-Ar date for the El Calderon flow (Laughlin et al., 1979) is 1.5 Ma, suggesting that canyon incision had occurred by at least this time. Although Grimm (1985) did not support this time of canyon incision, K-Ar dates from the Lucero uplift area (Baldridge et al., 1987) indicate that incision to within 60 m of modern base level had occurred by 1.1 Ma. Flows of this age are found on the “Mush Mesa” surface of Wright (1946; Baldridge et al., 1987). A tentative correlation is that the S2 surface of the Mt. Taylor region (Grimm, 1985) is correlative with the Mush Mesa surface (Wright, 1946). This surface formed after the 2-3 Ma flows on the S1 surface and before the 1.5-1.1 Ma flows on the S2 surfaces. Given these age ranges, the incision rates estimated by Grimm (1983) would be significantly higher.
Flows dated between 0.4 and 0.3 Ma are found on surfaces lower than S2 (Maxwell, 1982; Lipman and Mehnert, 1980; Baldridge and Perry, 1982). These flows appear to be developed on thick alluvial fills and not on pediment surfaces. Wright (1946) referred to this surface within the Lucero region as the "Suwanee" surface which rests upon ancestral Rio San Jose (?) gravels. This surface is tentatively correlated with the S3 surface of Grimm in the Mt. Taylor area. The thick alluvial-fan fill in the canyons surrounding Mt. Taylor may represent the same period of aggradation of the ancestral Rio San Jose.

Limited isotopic age constraints and tentative paleogeographic reconstructions imply regionally correlative episodes of uplift, erosion, pedimentation, incision, and aggradation over the boundary zone. The various periods of regionally correlative geomorphic events may reflect large-scale tectonic/crustal behavior. Detailed field studies and numerous cation-ratio dates are required to test the hypothesis proposed in this report and to elucidate the Late Cenozoic history of the region.

REFERENCES


alluvial and eolian deposits of this study
primarily in the Mesaverde Group (Triassic),
not exposed locally.

- sandstone and mudstone
- carbonaceous shale
- siltstone and mudstone
- limestone
- sandstone; locally crossbedded
- conglomerate
- tuff and volcanic breccia
- basalt
volcanic rocks

Cretaceous strata

Jurassic strata

Triassic strata

Figure 4.
Basalts and other volcanics of high mesas; generally > 2.5 m.y. old

Basalt flows of modern base-level drainages; generally < 0.5 m.y. old

Figure 5
(1) Armstrong and others, 1976
(2) Bachman and Mehnert, 1978
(3) Lipman and Mehnert, 1980
### Table 2

<table>
<thead>
<tr>
<th>no.</th>
<th>description</th>
<th>age (m.y.)</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>earliest trachyte</td>
<td>4.37+/-0.27</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>East Grants Ridge rhyolite</td>
<td>3.34+/-0.16</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>lower basalt</td>
<td>2.92+/-0.86</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Mesa Chivato basalt</td>
<td>2.87+/-0.20</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Mesa Chivato cinder cone</td>
<td>2.75+/-0.30</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>upper basalt; Encinal Mesa</td>
<td>2.65+/-0.15</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>late pyroclastic flow</td>
<td>2.6</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Horace Mesa</td>
<td>2.5</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Wheat Mountain basalt</td>
<td>2.42+/-0.18</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Mesa Prieta basalt</td>
<td>2.20+/-0.30</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>upper basalt</td>
<td>1.56+/-0.17</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>El Calderon flow</td>
<td>1.57+/-0.26</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Laguna flow</td>
<td>0.38+/-0.25</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>Suwanee flow</td>
<td>0.32+/-0.20</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>McCartys flow</td>
<td>0.001</td>
<td>5</td>
</tr>
</tbody>
</table>

(1) Armstrong and others, 1976  
(2) Bachman and Mehnert, 1978  
(3) Laughlin and others, 1979  
(4) Lipman and Mehnert, 1980  
(5) Nichols, 1946
<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Color(1), matrix (dry)</th>
<th>Texture (2)</th>
<th>Structure (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GEOMORPHIC SURFACE S2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0-11</td>
<td>10 YR 5/4</td>
<td>s1</td>
<td>---</td>
</tr>
<tr>
<td>B1t</td>
<td>11-14</td>
<td>7.5 YR 4/6</td>
<td>cl, sic</td>
<td>vf-f, sbk</td>
</tr>
<tr>
<td>B2t</td>
<td>14-33</td>
<td>5 YR 4/4</td>
<td>sic, c</td>
<td>f-m, abk</td>
</tr>
<tr>
<td>B3tca</td>
<td>33-50</td>
<td>7.5 YR 4/6</td>
<td>sic</td>
<td>f-c, abk</td>
</tr>
<tr>
<td>Cca</td>
<td>50-140+</td>
<td>10 YR 7/3</td>
<td>scl</td>
<td>m</td>
</tr>
<tr>
<td><strong>GEOMORPHIC SURFACE S2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Av</td>
<td>0-4</td>
<td>10 YR 7/3</td>
<td>s1</td>
<td>m</td>
</tr>
<tr>
<td>B2</td>
<td>4-10</td>
<td>5 YR 5/4</td>
<td>s1c</td>
<td>vf, abk</td>
</tr>
<tr>
<td>B32ca</td>
<td>10-20</td>
<td>7.5 YR 6/4</td>
<td>sc</td>
<td>vf-m abk</td>
</tr>
<tr>
<td>B33ca</td>
<td>20-28</td>
<td>7.5 YR 6/4</td>
<td>sc</td>
<td>m</td>
</tr>
<tr>
<td>Cca</td>
<td>28-50+</td>
<td>7.5 YR 7/4</td>
<td>s1</td>
<td>m</td>
</tr>
<tr>
<td><strong>GEOMORPHIC SURFACE S3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0-11</td>
<td>10 YR 5/4</td>
<td>s1</td>
<td>m</td>
</tr>
<tr>
<td>B</td>
<td>11-29</td>
<td>7.5 YR 5/4</td>
<td>s1</td>
<td>m</td>
</tr>
<tr>
<td>Cca</td>
<td>29-80+</td>
<td>7.5 YR 5/4</td>
<td>s1</td>
<td>m</td>
</tr>
<tr>
<td><strong>UNIT Qe1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td>0-30</td>
<td>7.5 YR 4/4</td>
<td>scl</td>
<td>f-c, sbk</td>
</tr>
<tr>
<td>B3</td>
<td>30-36</td>
<td>7.5 YR 5/6</td>
<td>s1</td>
<td>f-c, sbk</td>
</tr>
<tr>
<td>Cca</td>
<td>35-50+</td>
<td>7.5 YR 6/4</td>
<td>s1</td>
<td>m</td>
</tr>
<tr>
<td><strong>UNIT Qe1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>0-20</td>
<td>7.5 YR 5/4</td>
<td>scl</td>
<td>m</td>
</tr>
<tr>
<td>B2</td>
<td>20-35</td>
<td>5 YR 3/4</td>
<td>s1c</td>
<td>vf-m, abk</td>
</tr>
<tr>
<td>Cca</td>
<td>35-55+</td>
<td>5 YR 5/4</td>
<td>sc</td>
<td>m, gr</td>
</tr>
<tr>
<td><strong>UNIT Qe2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cn(Qe3)</td>
<td>0-35</td>
<td>7.5 YR 5/6</td>
<td>s</td>
<td>m</td>
</tr>
<tr>
<td>Ab</td>
<td>35-48</td>
<td>7.5 YR 5/4</td>
<td>s</td>
<td>m, sbk</td>
</tr>
<tr>
<td>Btb</td>
<td>48-53</td>
<td>5 YR 4/6</td>
<td>s1</td>
<td>c, sbk</td>
</tr>
<tr>
<td>Ccab</td>
<td>53-110+</td>
<td>7.5 YR 5/6</td>
<td>s</td>
<td>c-vc, sbk</td>
</tr>
</tbody>
</table>

(1) colors from Munsell Soil Color Charts  
(2) from Soil Survey Staff, 1981
MAP OF GEOMORPHIC SURFACES AND VOLCANIC LANDFORMS IN THE RIO SAN JOSE, A TRIBUTARY TO THE RIO PUERCO, WEST-CENTRAL NEW MEXICO

BY

STEPHEN G. WELLS
CONSULTANT

SUBMITTED TO:

DR. CHARLES D. HARRINGTON
LOS ALAMOS NATIONAL LABORATORY
ESS-1, MS D-462
P.O. BOX 1663
LOS ALAMOS, NEW MEXICO 87545

REPORT #2

NEOTEC, INC.
4045 SIMMS COURT SE
ALBUQUERQUE, NEW MEXICO 87108

APRIL 21, 1989
EXPLANATION OF MAP:

Symbol for maps: S = surface; 1-4 relative age of surface with 1 = oldest; v = volcanic; f = alluvial fans; p = pediment; u = undifferentiated; I-II = relative age of flows on given surface with I = oldest

Tertiary Surfaces:
Geomorphic Surface 1 & Overlying Pliocene Volcanic Units:
Surface is approximately 300 m above loval base level and is equivalent to the "Ortiz" surface of Bryan and McCann; surface predates flows dated 2.5 to 3.7 Ma

[S1v = pediment surface capped by Pliocene flows]

Early to Middle Pleistocene Surfaces:
Geomorphic Surface 2A:
Pediment surfaces that lie approximately 35-60 m above base level; surface predates Laguna flow near Laguna Pueblo which is 0.38 +/- 0.25 Ma

[S2ap = pediment surfaces capped with veneer of sediments]
[S2v = volcanic flows]

Geomorphic Surface 2B:
Alluvial fan surfaces approximately 6-20 m above base level; surface predates Laguna (El Cauldron) flow which is dated at 54 +/- 50 ka (Laughlin) and 124 +/- 33 ka (USGS) and surface map interfinger with 'Laguna Pueblo' flow?

[S2bf = alluvial fan surfaces]

Late Pleistocene Surfaces:
Geomorphic Surface 3:
Alluvial slopes and volcanic flows; flows include Laguna (El Cauldron) flow (54-128 ka) and perhaps flows of Bandera and Paxton Springs (undated but younger than Laguna)

[S3u = undifferentiated alluvial fan and pediment surfaces]
[S3vl = volcanic flows 54-128 ka]
[S3vII = volcanic flows < 54 ka and pre-Holocene]
Holocene Geomorphic Surfaces:
Geomorphic Surface 4:
Valley floor surfaces, colluvial side slopes, and volcanic flows; flows include McCarty's flow (approx. 1.3 ka) and may include parts of the Paxton Springs flow?; deposits below surface yield radiocarbon date of 2310+/−50 yrs BP (Grimm, 1985)

[S4u = undifferentiated alluvial, colluvial, and pediment surfaces]
[S4v = volcanic flows]

Undifferentiated Colluvial and Bedrock Surfaces:

[C/B = undifferentiated colluvial overlying bedrock and exposed bedrock]
REPORT # 3
GEOMORPHIC SURFACES OF THE
ZUNI/BANDERA/MALPAIS REGION,
WEST-CENTRAL NEW MEXICO

SUBMITTED TO

DR. CHARLES HARRINGTON
LOS ALAMOS NATIONAL LABORATORY
EES-1, MS D-462
P.O. BOX 1663
LOS ALAMOS, NEW MEXICO 87545

BY

DR. STEPHEN G. WELLS, CONSULTANT

NEOTEC, INC.
4045 SIMMS COURT SE
ALBUQUERQUE, NEW MEXICO 87131

AUGUST 1989
MAP OF GEOMORPHIC SURFACES

A generalized map of the aerial extent of Tertiary and Quaternary geomorphic surfaces was prepared as a base map for research during year 2, and this map is attached to the report. The map is a compilation from previous work and from field observations by the author of this report. Those reports which were used in compiling the map are McLellan et al. (1982) and Hunt (1978). A base map was prepared on mylar overlay at a scale of 1:250,000, and this map can be superimposed over standard U.S. Geological Survey 2-degree sheets. Reductions of this map are included in this report for the ease of reproductions.

The study area encompasses the region from latitude N34° 30' to N35° 30' and from longitude W108° to approximately W110°. The study area is bounded between Gallup, New Mexico to the north and Fence Lake, New Mexico to the south. The study area extends approximately 15 km into eastern Arizona.

MAP UNITS

Geomorphic surfaces are defined herein as a group of landforms that represent an episode of landscape development during a given time interval. Geomorphic surfaces are not time transgressive over long periods of geologic time and may be either erosional or aggradational in origin. Within this study, three major groups of geomorphic surfaces have been delineated on the basis of their height above regional base level, lithologic characteristic, and regional slope patterns. The units are discussed in detail below.

Unit T1: The oldest geomorphic preserved within the study area is defined as unit T1 and is informally referred to as the Santa Rita Mesa geomorphic surface. The geomorphic surface is named after the major mesa south of Fence
Lake where the surface is exposed so clearly. The Santa Rita Mesa surface is only preserved on mesa tops south of Atarque Draw.

The Santa Rita Mesa surface is underlain by a 70 m+ thick sequence of fluvial conglomerates and sandstones which unconformably overlie Mesozoic strata. These fluvial deposits were named the Fence Lake Formation by McLellan et al. in 1982. The basal part of the Fence Lake Formation is a coarse conglomerate with boulders of volcanic rocks (basalt, rhyolite) supported by granules, pebbles, and cobbles of similar lithologies (McLellan et al., 1982). Field observations indicate that pebble- to cobble-size clasts of granite occur within the deposit. The upper unit is primarily a weakly indurated sandstone with gravel lenses. Anderson's (1981) and Chamberlin's (1981) research suggests that the Fence Lake Formation is a northwest-trending, volcaniclastic alluvial fan derived from the Oligocene-age Datil volcanic field. These source rocks and the regional slope of the surface indicate a northwest flowing drainage systems during the formation of the Santa Rita Mesa geomorphic surface.

Although these deposits were previously considered to be equivalent to the Pliocene Bidahochi Formation, studies by McLellan et al. (1982) suggest the Fence Lake Formation is older and is perhaps Miocene in age. Field observations support a age difference between the Bidahochi and Fence Lake formations, as indicated on the attached map. Unit T2 which includes deposits mapped as Bidahochi equivalent are inset below the Santa Rita Mesa geomorphic surface.

Unit T2: The next youngest geomorphic surface preserved within the study area is mapped as unit T2 and is informally referred to as the Zuni geomorphic surface. The geomorphic surface is named for the exposures of
the surface north of the Zuni Pueblo. The Zuni geomorphic surface has more areal extent than unit T1 and occurs from 15 km south of Gallup to Fence Lake. The regional slope of the Zuni surface is westward (1) away from wind gaps in the Zuni Mountains and (2) away from local topographic bedrock highs or higher geomorphic surfaces (see attached map).

The Zuni geomorphic surface is underlain by deposits of the Bidahochi Formation. The Bidahochi Formation unconformably overlies Mesozoic strata. In northeastern Arizona, the Bidahochi Formation is composed of a basal argillaceous sandstone and mudstone with interbeds of white rhyolitic ash, a volcanic middle member with lava flows 30 m+ thick, and an upper fluvial sandstone and interbeds of white rhyolitic ash. The relative extent of each member with the study area is unknown; however, no middle volcanic members have been observed. Exposures north of Zuni Pueblo have lithologies similar to that of the upper member of northern Arizona.

The middle member of the Bidahochi Formation has been K-Ar dated at 6.7-4.1 Ma (see Report #1), indicating that the Zuni geomorphic surface postdates the early Pliocene. Age estimates of the Zuni geomorphic surface may be as young as earliest Pleistocene; however, the regional age of the surface is most likely 4-2 Ma. The Zuni geomorphic surface may correlate in age with the Ortiz geomorphic surface, upon which 3-2 Ma volcanic rocks of Mt. Taylor erupted. Further work is need to refine the age of the Zuni geomorphic surface is the study area.

Unit Q1-2: The youngest geomorphic surface within the study area is defined either as Q1, Q2, or Qu where Q1 represents early Pleistocene surfaces, Q2 represents middle Pleistocene surfaces, and Qu are undifferentiated Quaternary surfaces. This unit is informally referred to as the Malpais
geomorphic surface and is named for the volcanic terrain south and east of the Zuni Mountains. The surface is the most continuous and widespread surface in the southern and western parts of the study area (see attached map).

The Malpais geomorphic surface is underlain by Quaternary-age basalts derived from the Bandera/Chain of Crater region southeast of the Zuni Mountains. These surfaces are constructional in origin and formed as voluminous basalt flows drained westward down the ancestral valleys of the Zuni River and Atarque Draw. An early Pleistocene flow (approximately 1.0 Ma) extends across the New Mexico/Arizona boundaries and ends at the confluence of Zuni River and Atarque Draw. A middle Pleistocene flow (approximate 0.5 Ma) drained down the Zuni River and terminated near the present location of Zuni Pueblo. Detailed field mapping will be required to differentiate the different basaltic flows of the Malpais geomorphic surface. All flows, however, are inset well below the Zuni geomorphic surface and are confined within the valleys of the present-day landscapes.

INTERPRETATIONS OF GEOMORPHIC SURFACES

The following inferences can be made concerning the results of this mapping project:

1) A significant change in the regional slope of the study region occurred between the time of the Santa Rita Mesa and Zuni geomorphic surfaces. Unit T1 slopes north and west, and T2 surface slopes southwest and west. It is possible that renewed uplift in the Zuni Mountain region or areas to the north and east caused this regional adjustment of geomorphic surfaces.

2) The Zuni Mountains represent a major source area for the deposits of the Bidahochi Formation and its associated Zuni geomorphic surface. This surface
heads in wind gaps which cut through the hogback along the flank of the mountains. Perhaps, regional uplift of the Zuni Mountains and subsidence of the Zuni basin to the west resulted in the development of the Bidahochi deposits and Zuni geomorphic surface.

3) Subsequent to the Zuni geomorphic surface, the region experienced significant lowering of base level and the development of the modern landscapes; mesas and deep canyons. The development of the modern drainage systems with respect to their relative geographic position occurred prior to the development of the Malpais surface and after the Zuni surface. Perhaps, widespread uplift resulted in regional incision of the drainage systems in the study area, and following the uplift, basaltic eruptions filled in the canyon flows, burying much of the latest Pliocene and early Pleistocene landscapes.

REFERENCES
GEOMORPHIC SURFACES OF THE
ZUNI/BANDERA/MALPAIS REGION,
WEST-CENTRAL NEW MEXICO

PREPARED BY

STEPHEN G. WELLS
REPORT # 4
PROGRESS REPORT

SUBMITTED TO

DR. CHARLES HARRINGTON
LOS ALAMOS NATIONAL LABORATORY
EES-1, MS D-462
P.O. BOX 1663
LOS ALAMOS, NEW MEXICO 87545

BY

DR. STEPHEN G. WELLS, CONSULTANT

NEOTEC, INC.
4045 SIMMS COURT SE
ALBUQUERQUE, NEW MEXICO 87131

AUGUST 1989
SUMMARY OF PROGRESS IN THE ISR PROJECT

Rock varnish samples have been collected for use in construction of the rock-varnish dating curve for estimating ages of geomorphic surfaces in west-central New Mexico. Analysis of these rock varnish samples indicates that the rock varnish dating curve for west-central New Mexico may not be significantly different from the Espanola basin to the northeast. If this proves true, it will demonstrate that a single rock varnish curve is likely applicable to the non-mountainous region of central and northern New Mexico and an integrated curve for the period 22 to 1000 ka will be available for the second year of investigation.

A priority list of sites has been established where K-Ar dates are needed, and collection of volcanic rock samples for K-Ar dating has begun for ten samples. The ages of these samples are needed to determine the age of the volcanic features intimately associated with the geomorphic surfaces and whose age will provide necessary time constraints on their formation. Dating of these and other volcanic flows will also provide calibration ages for the rock varnish dating curve. These sites range in probable age from late Tertiary through the Quaternary based on analyses provided in *Reports 1-3 of Neotec, Inc.* and previous K-Ar of Laughlin and Perry. Several of these dates will be crucial in identifying and constraining the age and extent of the late Tertiary geomorphic surface, here referred to as either the Ortiz or Zuni geomorphic surfaces. These surfaces were not previously mapped or correlated across the study area until the preliminary mapping provided in *Reports 2 and 3 of Neotec, Inc.* This mapping is critical to the development of the late Tertiary and early Quaternary landscapes of west-central New Mexico. Detailed field mapping in these areas will be necessary to refine the reconnaissance maps provide in *Reports 2 and 3 of Neotec, Inc.*
A priority list of surfaces to be mapped in detail and dated by rock varnish has been established for the valley of the Rio San Jose and along the Arroyo Colorado, a major tributary of the Rio San Jose in this region. This priority list was based upon the preliminary mapping of *Report 2 of Neotec, Inc.* Detailed field work has been initiated and supports the general mapping of the geomorphic surfaces as illustrated in *Report 2 of Neotec, Inc.* Field examination of geomorphic surfaces and volcanic features within the Zuni Mountain region is ongoing and may provide a critical correlation over the study area for Miocene and Pliocene geomorphic surfaces. If the Zuni and Ortiz geomorphic surfaces are correlative, reconstructions of this surface may be possible for west-central New Mexico. This surface may represent the oldest reliable datum for establishing the rate of neotectonic deformation within this region. Mapping of these surfaces [as well as obtaining samples for K-Ar dating volcanic landforms] has been a major task through the last part of FY 1989.

During the course of this project, it has been determined that there exists a potential within the Rio Puerco Valley to not only use dates of volcanic maars and necks to provide age constraints for valley base level elevation, but to also date the timing and cutting of the Rio Puerco Valley in the region of the volcanic necks. Preliminary field observations of this region indicates that at least four major geomorphic surfaces exists and that they may correlate with those described in *Report 2 of Neotec, Inc.* Age control on valley cutting can be provided by obtaining rock varnish cation ratios along vertical transects on rock surfaces of the volcanic necks exposed during the cutting of the valley. These can be correlated and calibrated with soil-profile information on the surrounding geomorphic surfaces observed during this study.
MAJOR ACCOMPLISHMENTS DURING FY 1989

1. Defined four major geomorphic surfaces of the Lucero/Mt Taylor region, summarized their geomorphic properties, and made age estimates and tentative correlations with geomorphic surfaces recognized by previous workers and in other geographic locations within west-central New Mexico.

2. Proposed a tentative paleogeographic model of west-central New Mexico for landscape evolution during the Tertiary and Quaternary.

3. Provided a regional map of geomorphic surfaces for the Rio San Jose Valley, tributary to the Rio Puerco, in the region south of Mt. Taylor and recommended that the Encinal Valley might provide the most complete geomorphic history of any region along the Rio San Jose. Conducted field work to support this observation and direct a graduate research assistant to provide an more elaborate map of this region.

4. Provide a regional map of geomorphic surfaces for the Zuni/Malpais/Bandera region and to provide tentative age estimates based upon the published literature.

5. Conducted field work to (1) assist in sampling volcanic features and rock varnish samples, (2) field check maps of geomorphic surfaces, and (3) assist in guidance of graduate research assistant working on the ISR project.