An Investigation into the Western Coega Fault for Seismic Source Characterization of the Proposed Thyspunt Nuclear Site, Eastern Cape, South Africa.

J.S.V Reddering, D. Claassen, R. Coppersmith

Council for Geoscience
Report Number 2012-0030
Rev. 0

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To whom it may concern

Dr J.S.V. Reddering passed away before this report was completed, but Mrs Claassen took over and finalised it. It was therefore not possible to get Dr Reddering’s signature on this report.

E. Hattingh
Project Manager
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Executive Summary

This report documents the geological studies conducted to address the potential neotectonic reactivation of the Western Coega Fault corridor. The fault is associated with the east-west striking extensional Ceres-Kango-Baviaanskloof-Coega Fault system (CKBC). The investigation is one of several geological investigations conducted to provide data for the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 probabilistic seismic hazard analysis (PHSA) for the proposed nuclear power plant at Thyspunt.

The Western Coega Fault Zone (WCFZ) consists of two subparallel NW striking fault traces referred to as the primary (southern) and secondary (northern) Western Coega faults and is truncated in the west by a NE striking cross fault, referred to here as the Western Coega Cross Fault (WCCF). The objective was to identify both the primary and secondary fault zones in areas where the post-African I erosional surfaces are overlain by Neogene surfaces and deposits of silcretized river gravels, stratigraphically known as the Grahamstown Formation (Tg). These erosional surfaces are well developed in the KwaZunga valley, where most of WCFZ lies. The KwaZunga River prominently follows the southern, primary fault of the WCF system, however, the Tg surface is sporadically preserved and is generally less than 6 m thick.

A total of 14 sites were identified for investigation along the secondary Western Coega Fault (SWCF), the primary Western Coega Fault (PWCF) and WCCF.

Field reconnaissance at site WCCF-01 on the WCCF showed no vertical displacement of the Tg surface and no fault scarp at the surface. The Tg surface is intact and undeformed with no evidence of down-to-the-northwest faulting of the terrace gravels. Although such deposits are not found to overlie the cross fault along its entire length it is concluded that the WCCF has not been active in post-Miocene time.

Along the PWCF, site PWC-03 shows a 5 m thick Tg cap situated directly above the fault zone. The Tg surface is showed to be undisturbed and no evidence of a fault scarp or surface rupture is present at the site locality. Although the Tg surface and deposits are not present along the entire length of the PWCF, the evidence at site...
PWC-03 for no post-Tg displacement provides support to the conclusion that the PWCF shows no evidence of neotectonic displacement.

Sites of highest priority along the SWCF are: SWC-02, SWC-03, and SWC-05. At these three sites the fault clearly cuts bedrock underlying the Tg surface and no evidence of displacement of the overlying material as observed in aerial photographs and in field observations. Based on the results and observations from field work the secondary fault does not displace a large Tg terrace remnant at site SWC-06. No fault scarp is observed in aerial photographs of the entire secondary fault trace except in Paleozoic bedrock.

Based on the field evidence collected and cosomogenic results (Bierman 2012) that show a lack of evidence suggestive of neotectonic activity in the last 2-3.7 My or at least since the Pleistocene, coupled with the slow erosion rates of 5.4m/My, the area that includes the WCF is indicative of a stable tectonically landscape and an inactive WCF. Such slow erosion rates coupled with the pre-Pleistocene age of the Tg surface would suggest that if fault scarps were formed, they would still be visible in the landscape today. Thus the absence of scarps or displacement of the Tg surface and deposits along the WCF is indicative of an inactive fault since at least earliest Pleistocene time (Bierman 2012).
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List of Acronyms

AFFZ       Agulhas-Falkland Fracture Zone
CGS        Council for Geoscience
CKBC       Ceres-Kango-Baviaanskloof-Coega
GE         Google Earth
GEP        Google Earth Pro
GPS        Global Positioning System
Ma         Million
My         Million years
PSHA       Probabilistic Seismic Hazard Analysis
PWCF       Primary Western Coega Fault
QCP        Quality control plan
SSHAC      Senior Seismic Hazard Analysis Committee
SSR        Site Safety Report
SWCF       Secondary western Coega Fault
Tg         Tertiary Grahamstown Formation - refers to the high level terrace gravels cemented by silcrete mapped as the Grahamstown Formation
TMG        Table Mountain Group
WCF        Western Coega Fault
WCCF       Western Coega Cross Fault
WCFZ       Western Coega Fault zone
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<tr>
<td>Breccia</td>
<td>A coarse-grained clastic rock composed of angular broken rock fragments held together by a mineral cement or in a fine-grained matrix – in this report the origin of which is related to tectonic processes.</td>
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<tr>
<td>Cenozoic</td>
<td>Last 65 million years; an era of geological time from the beginning of the Tertiary period (65 million years ago) to present.</td>
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<tr>
<td>Caprock</td>
<td>Caprock is a harder or more resistant rock type (in this report silcretised terrace gravels) overlying a weaker or less resistant rock type or structure (in this report the fault zone).</td>
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<tr>
<td>Cretaceous</td>
<td>The final period of the Mesozoic era thought to have covered the span of time between 135 and 65 million years ago.</td>
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<tr>
<td>Cross-fault</td>
<td>A fault whose strike crosses at a high angle the strike of the constituent strata or the general trend of the regional structure; also the minor fault that intersects a major fault.</td>
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<tr>
<td>Displacement</td>
<td>A general term for the relative displacement of both sides of the two sides of a fault, measured in any chosen direction.</td>
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<tr>
<td>Epicentre</td>
<td>The location on the surface of the earth directly above the focus, or place where an earthquake originates from within the earth’s crust.</td>
</tr>
<tr>
<td>Fault</td>
<td>A fracture or a zone of fractures along which there has been displacement of the sides relative to one another parallel to the fracture.</td>
</tr>
<tr>
<td>Fault scarp</td>
<td>The feature on the surface of the earth that looks like a step caused by slip on the fault; it is a topographically visible feature.</td>
</tr>
<tr>
<td>Fault trace</td>
<td>The intersection of a fault with the ground surface; also the line commonly plotted on geological maps to represent a fault.</td>
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<tr>
<td>Fault zone</td>
<td>A fault that is exposed as a zone of numerous small fractures or of breccia or fault gouge.</td>
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<tr>
<td>Holocene</td>
<td>An epoch of the Quaternary period, from the end of the Pleistocene, approximately 10 000 years ago, to the present time; also corresponding to the series of rocks and deposits.</td>
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<tr>
<td>Neogene</td>
<td>An interval of time incorporating the Miocene and Pleistocene of the Tertiary period; the later Tertiary.</td>
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<tr>
<td>Neotectonics</td>
<td>The study of post-Miocene structures and structural geology of</td>
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| **Normal fault** | A fault in which the hanging wall (the block above the fault plane) appears to have moved downward relative to the footwall. The fault angle is usually between 45-90°. |
| **Offset** | In a fault, the horizontal component of displacement, measured perpendicular to the disrupted horizon. |
| **Ordovician** | The second earliest period of the Paleozoic era, thought to have covered the span of time between 500 and 440 million years ago; also the corresponding system of rocks. |
| **Orogeny** | Literally, the process of formation of mountains. |
| **Paleo (pre-fix)** | Denoting the attribute of great age or remoteness in regard to time, or involving ancient conditions. |
| **Paleozoic** | An era of geological time, from the end of the Precambrian to the beginning of the Mesozoic, or from about 570 to about 225 million years ago. |
| **Quaternary** | The second period of the Cenozoic era, following the Tertiary; also the corresponding system of rocks. It began two to three million years ago and extends to the present. |
| **Saddle** | A low point in the crest line of a ridge. |
| **Scarp** | A long, more or less continuous cliff-face or step/ridge formed by sudden earth displacements (usually vertical) along fault lines. Scarps may also be formed by horizontal displacement, where a hill or ridge has been broken open, exposing a steep interior face along the line of the rupture. Scarps may be erosional as well. |
| **Scree** | Broken rock fragments; a heap of such fragments; and the steep slope consisting of such fragments (also known as talus). |
| **Silcrete** | A conglomerate consisting of superficial sand and gravel cemented into a hard mass by silica. |
| **Terrace** | A long narrow, relatively level or gently inclined surface, generally less broad than a plain, bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope. |
1. Introduction and Terms of Reference

The Council for Geoscience (CGS) was tasked to investigate the geological conditions around the proposed nuclear power station at Thyspunt, south of Humansdorp. Site Safety Report (SSR) investigations at Thyspunt were undertaken during the first half of 2008. In early 2009 and again in 2010, the CGS was tasked with conducting additional geological investigations to evaluate potential seismic sources for the Thyspunt probabilistic seismic hazard analysis (PSHA), as part of the broader Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 assessment process. A task team was formed to investigate the main fault corridors along selected major faults in the Eastern Cape.

This report addresses studies conducted along the western Coega Fault segment of the east-west striking extensional Ceres-Kango-Baviaanskloof-Coega Fault system (CKBC) (Figure 1). The Coega Fault corridor has been further subdivided into an ‘upper’, western Coega Fault sector and ‘lower’, eastern Coega sector (Figure 5) based on host rock characteristics. This study will only focus on the western Coega Fault Zone (WCFZ) which consists of two subparallel NW striking traces referred to as the primary (southern) and secondary (northern) faults, and is truncated in the west by a NE striking fault, referred to in this report as the Western Coega Cross fault (WCCF).

The primary objective of this study was to map portions of the fault zone where data could be gathered to assess the location and activity of the WCFZ. Mapping of the WCFZ also provides additional information that can be used to assess the relationship between different fault traces within the CKBC fault system, including the Pleistocene active segment of the Kango Fault (Goedhart, 2005, 2006 and Hanson et al, 2012). This information will be used to assess the potential for reactivation of the WCFZ in the present tectonic stress regime. A separate investigation of the eastern Coega Fault Zone near the coast, based on interpretation of subsurface data, was conducted by Mitha et al. (2012).

In addition to mapping investigations conducted at selected sites along the WCFZ, the evaluation of evidence for neotectonic fault reactivation also included a desktop review of pertinent information and a geochronologic program that included sampling of rock material for the purpose of cosmogenic radionuclide dating (Bierman 2012).
Figure 1: Fault corridors along the southern Cape coast included in the Thyspunt Geological Investigations program to support the SSAC 3 PSHA study. Hillshade has been applied to the figure to accentuate the dramatic topography of the study area. The Western Coega Fault is located between the Groot Winterhoek Mountains towards the north and the Elende Mountains towards the south.
The study was conducted by the Council for Geoscience in association with AMEC E & I, Inc. for ESKOM, under Contract No. 4600025329. The investigation was conducted according to the Integrated Management System (Hattingh et al. 2010), and more specifically in accordance with the site specific quality control plan for the Western Coega Fault investigation (QCP reference no:TNSP-GIA-QCP-10-T2-D), for the purposes of seismic source characterization of the Thyspunt site.

1.1 Background

All potential seismic sources, in this case potentially capable faults, within the region around the proposed nuclear site situated at Thyspunt are studied to determine their rate of re-occurrence and rate of slip as part of the PSHA for the Thyspunt site.

The Coega Fault forms part of the E-W extensional CKBC fault system which could include potential fault sources of importance to the Thyspunt PSHA. Recent investigations (Goedhart 2004, 2005, 2006 and McCalpin 2009) have shown that a portion of the fault system, namely the Kango Fault, displays evidence of Quaternary reactivation. It is therefore important to determine if other faults of the system display similar evidence of geologically-recent displacement, such that their seismogenic potential can be assessed in the PSHA.

1.2 Scope and Objectives

The CKBC fault system is divided into fault specific corridors that were earmarked for investigation (Figure 1). The Coega Fault corridor is further subdivided into an ‘upper’ or western Coega sector and ‘lower’ or eastern Coega sector based on host rock characteristics. This study will only focus on the WCF sector. A separate investigation into the eastern Coega Fault Zone and the transition zone between the western- and eastern Coega Fault Zones was conducted by Mitha et al. (2012).

Objectives of the WCF investigations are:

1) Where possible confirm the presence of the WCF in the field relative to its currently mapped location according to the 1: 250 000-scale, 3324 Port Elizabeth geological series (South African Geological Survey 1991).
2) Locate areas along the WCF where the possibility of neotectonic displacement can be investigated.
3) Investigate sites identified as possible indicators for neotectonic displacement and where evidence can be gathered confirming the absence of neotectonic displacement
4) In light of all the evidence gathered during the course of the investigations, assess whether or not the WCF has undergone reactivation since the Mesozoic and the age of the most recent displacement.

2. Geologic and Geomorphic Setting

2.1 Major Deformational Events

Structures within the Cape Fold and Thrust Belt have experienced multiple periods of deformation and reactivation. Toerien and Hill (1989) suggested that the faults produced during the Cape Orogeny were reversed during subsequent tensional stresses and produced the normal faulting observed in Paleozoic and Mesozoic rocks along the CKBC fault system.

The study of the tectonic origin of the CKBC fault system provides evidence that the faults investigated in this study formed contemporaneously. Gresse at al. (1992) used radiometric 40Ar/39Ar dating to determine the age peaks of pulses of compressional tectonics of the Cape Orogeny at 294Ma, 276MA, 259Ma, 239Ma and 223Ma, leading to mountain building, followed by an extensional rifting period with a dated peak at 177Ma. Hälbich (1992) recognized roughly the last four of Gresse et al.’s dated pulses.

Historically, most of the work on the Cape Fold Belt has been carried out at its western sector. Booth and Shone (1992) described the characteristics of the Cape Orogeny in the area of Port Elizabeth, near the eastern end of the Cape Fold belt. Tight asymmetrical folds verge northeastward whereas gentle cross folds are superimposed. Low-angle-thrust faults are associated with the tight faults in some areas with the thrust surfaces lying close to horizontal or dipping southward. In places the thrust faults display an imbricate structure. Bedding is locally completely overturned and extends over a large area of Port Elizabeth, interpreted as a large recumbent fold. The substantial thickness of the quartzite of the Table Mountain Group (TMG) in the area is interpreted by Booth and Shone as resulting, at least in part, from duplication by thrusts. Normal faults are interpreted as the youngest tectonic features of the area. A similar relationship between folded quartzite of the TMG superimposed by younger normal faults is observed throughout the western Coega Fault corridor. The tectonic succession is therefore the same as elsewhere in
the Cape Fold Belt, composed of a period of compression followed by extension. This extension is interpreted by Gresse et al. (1992) as being associated with the fragmentation of Gondwana.

The onshore and offshore rifts along the southern and southeastern coasts of South Africa, including the project area and the WCFZ are interpreted by Şengör (1995) as having formed by shearing along the proto-Agulhas-Falkland Fracture Zone (AFFZ) in Gondwana. The transverse separation of South America from the southern African subcontinent took place along the AFFZ.

Newton et al. (2006) reviewed the tectonics of the Cape Orogeny and arrived at the same conclusions as the authors above, namely compression with four pulses of crustal shortening, followed by extension associated with the fracturing of Gondwana. Compression was associated with folding and thrust-faulting, whereas the extension led to normal faulting along existing thrust-generated weakness in the Cape Fold Belt.

2.2 Geomorphology

In geomorphological terms, the high interior plateau of Gondwana with the Cape Fold Mountains standing above this plateau was subjected to vigorous landscape erosion after the fragmentation of Gondwana, as new erosional base levels established themselves. The resistance to weathering and erosion of much of the quartzite-dominated fold belt caused the mountains to remain relatively high above the surrounding landscapes. The African Erosion Surface is a continent-wide surface (Burke and Gunnel 2008) but has local, site-typical variants. The African Erosion Surface stabilized from the Late Cretaceous to the Miocene and developed a mature landscape. Subsequent crustal elevation produced the Post-African I erosion surface, which is the product of a shorter-lived planation and is therefore commonly stepped. Post-Pliocene uplift and tilting, for which there is local evidence of continued crustal elevation, and which was more substantial than for the development of the post-African I planation, has created a youthful landscape with deeply incised valleys with limited remnants of the older erosion surfaces imperfectly preserved on the higher ground (Figure 2). The older African Erosion Surface has been subjected to phases of crustal uplift and is least preserved
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These surfaces are well developed in the KwaZungua valley, which encompass almost the entire WCFZ (only the southwestern part of the cross fault extends beyond the watershed), and the KwaZungua River prominently follows the southern, primary fault of the WCF system. There is some evidence of the African Surface high up on the northern valley slopes (Figures 3 & 4). There is then a step down to what is most likely the Post-African 1 surface and that slopes down to the terrace set above the incised KwaZungua River valley (Figures 3 & 4).

The erosion surfaces are most commonly subaerially exposed, covered only by thin soil and vegetation. In several places there are fluvial-conglomerate deposits that overlie the erosion surface. These conglomerate deposits of the Cenozoic Grahamstown Formation are bound by ferruginous silcrete deposits. They cover the sloping terraces from the higher valley elevations down to just above the incised valley axis, and are most commonly best preserved near the valley axis. Although locally uncommon, these conglomerate units also lie on the African Erosion Surface, so that the Grahamstown Formation is substantially diachronous. Silcrete exposures are generally less than 6 m thick (Toerien and Hill 1989). For the purposes of this project these high level terrace gravels surfaces of the Grahamstown Formation may will be referred to as “Tg surfaces”.

3. Previous Investigations

In part due to the project area’s remote locality; difficult accessibility due to the dramatic landscape topography of deep valleys and hills, the area that includes the WCF has not been studied in great detail. Certain areas can only be reached by an extensive hike on foot or by helicopter. Access to areas is further hindered by the difficulty in contacting landowners and obtaining permission to access private property and use locked farm gates in the area.

The main sources of site specific information (geological and structural) available prior to field reconnaissance include:

- Unpublished master geological maps (Council for Geoscience)
- Post-graduate studies undertaken (unpublished)
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The downloaded document is uncontrolled; therefore the user must ensure that it conforms to the authorised database version.
Unpublished geological maps of the area on a 1: 50 000-scale that were compiled for the 1: 250 000-scale 3324 Port Elizabeth (Table 1) map published in 1991 (South African Geological Survey, 1991) are the main source of geological information within the context of the project. The eastern part of the Coega Fault was mapped on a 1:10 000-scale, but this more detailed mapping did not include the western part of the WCFZ, where suitable Neotectonic deposits and surfaces are present that can be used to assess neotectonic activity.

Table: 1: List of geological maps used in the WCF investigation.

<table>
<thead>
<tr>
<th>Mapsheet</th>
<th>Scale</th>
<th>Year</th>
<th>Mapped by</th>
<th>Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>3324DB Cockscomb</td>
<td>1: 50 000</td>
<td>1979-1983</td>
<td>D.K Toerien</td>
<td>Unpublished</td>
</tr>
<tr>
<td>3325CA Strydomsberg</td>
<td>1: 50 000</td>
<td>1979-1983</td>
<td>D.K Toerien</td>
<td>Unpublished</td>
</tr>
<tr>
<td>3325CB Uitenhage (North)</td>
<td>1: 50 000</td>
<td>1979-1983</td>
<td>D.K Toerien</td>
<td>Unpublished</td>
</tr>
<tr>
<td>3324 Port Elizabeth</td>
<td>1: 250 000</td>
<td>1991</td>
<td>D.K Toerien et al</td>
<td>Published</td>
</tr>
</tbody>
</table>

Ingram (1998) prepared a dissertation that presented a structural analysis within the bedrock portion of the Coega Fault in the area of transition between the eastern and western sectors. The study outlined different compressional-structural episodes during the Cape Orogeny in the area just west of Uitenhage. The author was able to follow the succession of four compressive paroxysms (Hälbich 1992) which produced folds of varying styles and a history of fold-associated thrust-faulting. The strike of the structural fabric extends from just north of Uitenhage, west-northwest for about 15 km to the area just west of the Groendal dam. This study confirmed that the overall tectonic motif changed from compressive orogenesis in the late Paleozoic to extension in the Mesozoic that produced associated intermontane rift basins. The author concludes that the Coega Fault system accommodated significant normal offset during the Cretaceous, and displaced the folded rock masses along zones of existing weakness produced by the thrusts formed during the preceding compression.
Further, the associated local rift basin formed by the post-orogenic extension is the proximal part of the Uitenhage Trough, a half graben that extends eastward to form part of the complex Algoa Basin. Coarse, quartzitic river gravel (Enon Formation) and more distally graded fluvial sand and mudstone (Kirkwood Formation) accumulated in this proximal half graben. The folded rock mass that was displaced by normal rift-faulting, and hosts the resultant half-graben basin, consists of the lower quartzite-dominated formations of the TMG. The study provides an analysis of the complex structural history of displacement along the fault system in the Paleozoic through the Cretaceous. The author did not investigate the potential for post-Mesozoic displacement along the fault system, however, the understanding of the fault location, orientation, and history provides a framework for understanding the present day structural setting.

Historically, most of the paleoseismic investigations of the Cape Fold Belt have been carried out in its western sector because there is evidence for Quaternary displacement along portions of the Kango Fault. However, as part of an assessment of the entire fault system Goedhart (2004) prepared a pre-field desk study of potential Neogene to Quaternary reactivation of the CKBC fault system between Cape Town and Port Elizabeth. After an extensive aerial photography interpretation, a total of 352 sites of interest were selected for further investigation into potential neotectonic displacement, of which 8 sites (Table 2) were situated along the WCFZ. Although many of the sites were visited, none of the 8 western Coega sites were investigated by a field reconnaissance. As stated by Goedhart (2004); sites with little or no evidence of neotectonic displacement were not visited – these sites were regarded as low priority sites.

Landscape features used to determine potential reactivation along the fault by Goedhart (2004) included identification of a fault scarp at the surface, offset or disturbance of younger overlaying sediments (terrace gravels, scree or colluvium) and occurrence of landslides. Goedhart (2004) identified little evidence of Tertiary reactivation along the WCF, but did state that more detailed field mapping should be undertaken.
Table 2: A modified extract of Appendix 7 in Goedhart (2004) shows the features of potential reactivation of the WCF identified using 1:10000 black and white aerial photos. Map particulars, geomorphic type of feature, coordinates, cadastral data, comment/interpretations and whether the site is considered a possible fault-reactivation site are indicated. This table refers to both the primary (southern) trace and secondary (northern) trace of the WCF. Goedhart referenced the western Coega Fault as the ‘Baviaans(kloof)’ Fault. The table below is corrected to read the ‘Coega Fault’.

*Note: There were duplication and numbering mistakes in the original list corrected in the table below.*

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Mapsheet</th>
<th>Geomorphic/Structural Feature</th>
<th>Comment</th>
<th>Potential Reactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1.008</td>
<td>S33°36'41&quot; E24°54'08&quot;</td>
<td>3324DB</td>
<td>Lack-of-feature report</td>
<td>No scarp or other features of potential interest occur along this primary fault set.</td>
<td>No</td>
</tr>
<tr>
<td>K1.009</td>
<td>S33°36'34&quot; E24°57'07&quot;</td>
<td>3324DB</td>
<td>Landscape terrace capped by silcrete cutting across the trace of the Coega Fault</td>
<td>The trace of the fault crosses a Late Cretaceous landscape terrace capped by silcrete. No scarp is evident there, and its absence would indicate a lack of neotectonic activity, post the Late Cretaceous Period.</td>
<td>No</td>
</tr>
<tr>
<td>K1.010</td>
<td>S33°38'49&quot; E25°05'48&quot;</td>
<td>3325CA</td>
<td>Hill-slope scree colluvium lying across the fault trace</td>
<td>The fault trace crosses the scree deposit on a steep hillslope. A scarp may be developed in this scree if neotectonic activity has locally taken place, but no scarp evident on the aerial photograph.</td>
<td>No</td>
</tr>
<tr>
<td>K1.011</td>
<td>S33°41'13&quot; E25°15'00&quot;</td>
<td>3325CA/CB</td>
<td>Lack-of-feature report</td>
<td>No scarp or other features of potential interest along this length of a primary fault set.</td>
<td>No</td>
</tr>
<tr>
<td>K2.004</td>
<td>S33°36'27&quot; E24°57'46&quot;</td>
<td>3325DB</td>
<td>Lack-of-feature report</td>
<td>No scarp or other features of potential interest along this secondary fault set.</td>
<td>No</td>
</tr>
<tr>
<td>K2.005</td>
<td>S33°37'49&quot; E25°02'44&quot;</td>
<td>3325CA</td>
<td>Landscape terrace capped by silcrete cutting across the trace of the Coega Fault.</td>
<td>The trace of the Coega Fault crosses a Late Cretaceous landscape terrace capped by silcrete in three places. No scarp is evident there, and its absence would indicate a lack of neotectonic activity.</td>
<td>No</td>
</tr>
<tr>
<td>K2.006</td>
<td>S33°39'00&quot; E25°10'42&quot;</td>
<td>3325CA</td>
<td>Hill-slope scree colluvium lying across the fault trace</td>
<td>The Coega Fault trace crosses the scree deposit on a steep hillslope. No scarp evident on the aerial photograph, hence lack of Neotectonic activity in post date Cretaceous.</td>
<td>No</td>
</tr>
<tr>
<td>K2.007</td>
<td>S33°38'50&quot; E25°18'41&quot;</td>
<td>3325CB</td>
<td>Lack-of-feature report</td>
<td>No scarp or other features of potential interest along this secondary fault set.</td>
<td>No</td>
</tr>
</tbody>
</table>
4 Site Investigations

4.1 Defining the Geology and Structure of the Western Coega Fault

For the purposes of the project the Western and Eastern Coega Fault zones are distinguished by their host-rock characteristics. The Coega Fault is laterally continuous from the western to the eastern sector, so the distinction is not based on fault discontinuity.

In the Eastern Coega Fault sector (Figure 5), to the east of Uitenhage, referred to in pre-2010 documentation as the “lower Coega Fault”, the fault crosses the Algoa Basin and exclusively displaces the Early Cretaceous bedrock at the basin surface, and is characterized by down-faulting to the south of the ESE–WNW-striking fault. The half graben formed by this down-faulting generated the Uitenhage Trough, the southern sub-basin of the Algoa Basin (Shone 2006). At the surface the Kirkwood and Sundays River Formations occur on the south side of the fault. These predominantly argillaceous formations erode easily, readily form soil and are covered by dense bush. The seaward, or eastern, half of the eastern Coega Fault is also overlain by Cenozoic deposits, mainly the Alexandria Formation, but also the younger Salnova and Schelm Hoek Formations. This Cenozoic cover presents the possibility of observing Neogene reactivation of the Coega Fault (Goedhart 2004, 2005 and 2006). In general the fault is poorly exposed and location of the fault trace is therefore uncertain. The Early Cretaceous Kirkwood and Sundays River Formations, through which the eastern Coega Fault runs and locally forms the faulted contact, can be distinguished based on:

- Colour; the Kirkwood Formation is characterized by red and green variegated beds, whereas the Sundays River Formation is uniformly a drab yellow-grey, and,
- Fossil content; the Sundays River Formation contains a variety of distinctive Early Cretaceous marine fossils (Engelbrecht et al. 1962) and microfossils (McMillan 2003), whereas the fluviogene Kirkwood Formation generally lacks these fossils.

A transition zone from the eastern to the WCFZ lies in the area of the town Uitenhage (Figure 5). This transition forms the faulted contact between the Early Cretaceous Uitenhage Group and the Palaeozoic Cape Supergroup over a distance of 15 km between Uitenhage and the Groendal Dam on the KwaZungu River. The quartzitic rocks of the Cape Supergroup form prominent hills to the north of the fault, and the
Kirkwood and Enon Formations to the south of the fault occupy a half graben and at the surface display a more subdued landscape.
For the purpose of the project this transitional fault sector was not prioritized because no Cenozoic bedrock caps the fault trace, and therefore there are no useful datums that will show the presence or absence of Neogene reactivation of the Coega Fault.

The WCFZ (Figure 5), referred to in pre-2010 documentation as the "upper Coega Fault", extends 30 km to the west of the Groendal Dam in the KwaZunga River valley and terminates against a cross fault at its west-northwestern limit. The western Coega Fault is of interest to the project because it is developed entirely in Palaeozoic quartzite of the TMG, is comparatively easy to trace, and the fault trace is locally capped by Cenozoic silcrete-cemented river conglomerate of the Grahamstown Formation. The unconformity at the base of the Tg is well exposed as is the geomorphic surface at the top of the deposit and these allow the possibility of checking for neotectonic reactivation of the Cretaceous fault. The WCFZ is characterized by two parallel faults of which the southern one is considered the primary fault and lies mostly in the incised KwaZunga River valley, whereas the trace of the secondary fault lies to the north is more prominently positioned along the post-African erosion surface on the hills above the river.

It must be noted that the terminology of primary and secondary allocated to the two fault traces is only based on office-based nomenclature. There is no data to suggest that either fault is more likely to be reactivated or experience greater displacement if reactivated. The primary and secondary fault trace nomenclature was given solely as a way of distinguishing the faults from each other.

The cross fault at the west-northwestern end of the WCF terminates both traces of the WCFZ (Figures 2 & 5). This cross fault is locally capped by the silcrete conglomerate of the Grahamstown Formation and can equally be inspected for neotectonic reactivation. As such it is for convenience considered part of the WCFZ. The WCFZ at the surface is contained entirely in the folded strata of the TMG (Cape Supergroup). The Ordovician Peninsula Formation is the basal unit of this succession. It is overlain in turn by the siltstone-dominated Cedarberg Formation (not shown on the published map, but was identified in the field during this investigation), mixed mudstone and quartzitic Goudini Formation and the quartzitic Skurweberg Formation. The overlying Baviaanskloof Formation lies near the fault zone but is not intersected by it at the surface. The Sardinia Bay Formation (sensu lato, Reddering, in prep.) below the Peninsula Formation also abuts the fault over to the east but in the transitional area, and is therefore not of any interest to the project.
As noted above in Section 2.1, this succession of the TMG was folded and subjected to thrust-faulting during four-pulses of the Cape Orogeny (Early Permian – Late Triassic) (Gresse et al. 1992; Hälbich 1992). This folded succession experienced a tectonic change from a crustal compressive regime to one of extension that displayed its earliest evidence in the interior with intrusion of the Karoo dolerite (183 Ma; Duncan and Marsh 2006), and eventually led to the fragmentation and dispersal of Gondwana. In the process the previously thrust-faulted crustal rock mass of the Cape Fold Belt experienced extensional rift-basin faulting. The main fault systems extending east-west across the breadth of the Cape Fold Belt originated during this period, extending from Ceres in the west to Algoa Bay in the east, and remained active well into the Late Cretaceous (Bate and Malan 1992). The later-phase activity, much of it associated with post-Gondwana thermal subsidence of the crust, was much reduced compared to the Jurassic to Early Cretaceous faulting during continental break-up.

4.2 Site Selection and Accessibility

To initially establish which field sites to visit, it was necessary to determine from existing and new data sources where best to observe whether or not Neogene Tg surfaces and deposits are present and if so, are they displaced by the WCF.

1. Recognize the target fault clearly
2. Identify Neogene deposits that overlie the fault, and
3. Each site must be practically accessible.

Points 1 and 2 can be achieved using remote sensing, mostly from aerial photographs. Point 3 can to a degree be done this way, but gate access and local conditions can only be established by field reconnaissance; only then one can undertake productive field investigations.

Goedhart, 2004 (Appendix A7) lists an aerial photograph interpretation of the fault sites east of the Kango Fault system and others in the area associated with the Mesozoic extension of the Cape Fold Belt, including the WCF system. During the preparation the current authors looked at the aerial photographs listed by Goedhart (2004) to confirm that these were the most suitable places to visit. These were also compared to the images of Google Earth Pro (GEP). It soon became apparent that the GEP images were superior to the aerial-photographic record, that site selection
was much faster and that site coordinates could far more rapidly be accessed to be transferred to GPS receivers. Since this change of technique represents a deviation of project procedure, the justification for it is presented in Appendix WC01. The outcome was that selection of sites was redone using GEP and presented as a new series of site targets with new site codes (Table 3 & Figure 6).

Table 3: The primary sites identified using remote sensing (GEP). Not all these sites are practically accessible.

<table>
<thead>
<tr>
<th>Site</th>
<th>South Dec °</th>
<th>East Dec °</th>
<th>South Dec °</th>
<th>East Dec °</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary western Coega Fault:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PWC01</td>
<td>-33.604599</td>
<td>24.92263</td>
<td>S33°36'16.6&quot;</td>
<td>E24°55'21.5&quot;</td>
</tr>
<tr>
<td>PWC02</td>
<td>-33.608187</td>
<td>24.93938</td>
<td>S33°36'29.5&quot;</td>
<td>E24°56'21.7&quot;</td>
</tr>
<tr>
<td>PWC03</td>
<td>-33.610067</td>
<td>24.9514</td>
<td>S33°36'36.2&quot;</td>
<td>E24°57'05.0&quot;</td>
</tr>
<tr>
<td>PWC04</td>
<td>-33.621804</td>
<td>24.99217</td>
<td>S33°37'18.5&quot;</td>
<td>E24°59'31.8&quot;</td>
</tr>
<tr>
<td>PWC05</td>
<td>-33.639142</td>
<td>25.05184</td>
<td>S33°38'20.9&quot;</td>
<td>E25°03'06.6&quot;</td>
</tr>
<tr>
<td>PWC06</td>
<td>-33.648584</td>
<td>25.09611</td>
<td>S33°38'54.9&quot;</td>
<td>E25°05'46.0&quot;</td>
</tr>
<tr>
<td>PWC07</td>
<td>-33.658964</td>
<td>25.16323</td>
<td>S33°39'32.3&quot;</td>
<td>E25°09'47.6&quot;</td>
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<tr>
<td>Secondary western Coega Fault:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWC01</td>
<td>-33.601756</td>
<td>24.92554</td>
<td>S33°36'06.3&quot;</td>
<td>E24°55'32.0&quot;</td>
</tr>
<tr>
<td>SWC02</td>
<td>-33.610625</td>
<td>24.97504</td>
<td>S33°36'38.2&quot;</td>
<td>E24°58'30.2&quot;</td>
</tr>
<tr>
<td>SWC03</td>
<td>-33.61596</td>
<td>24.99537</td>
<td>S33°36'57.5&quot;</td>
<td>E24°59'43.3&quot;</td>
</tr>
<tr>
<td>SWC04</td>
<td>-33.62148</td>
<td>25.01899</td>
<td>S33°37'17.3&quot;</td>
<td>E25°01'08.4&quot;</td>
</tr>
<tr>
<td>SWC05</td>
<td>-33.627374</td>
<td>25.02966</td>
<td>S33°37'38.5&quot;</td>
<td>E25°01'46.8&quot;</td>
</tr>
<tr>
<td>SWC06</td>
<td>-33.631302</td>
<td>25.05037</td>
<td>S33°37'52.7&quot;</td>
<td>E25°03'01.3&quot;</td>
</tr>
<tr>
<td>Western Coega Cross Fault:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCCF01</td>
<td>-33.614472</td>
<td>24.90107</td>
<td>S33°36'52.1&quot;</td>
<td>E24°54'03.8&quot;</td>
</tr>
</tbody>
</table>

Accessibility to the selected sites was often hindered by:

- Absentee landlords, with or without locked gates
- Neglect over time of access routes
- Ignorance of landowners about the access on neighbouring farms or property ownership thereof
- Generally inaccessible terrain
- Operational and safety concerns

A description of access to the sites visited, and to those that are practically accessible, but weren’t reached for some reason, is given in Appendix WC02.
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4.3 Field Reconnaissance and Results

4.3.1 Western Coega Cross Fault

4.3.1.1 Site WCCF-01

Site locality WCCF-01 (S33°36'52.1" E24°54'03.8") is positioned on the 4 km, NE-striking cross fault trace mapped to truncate the primary and secondary WCF traces (Figures 6 and 7). It is the only site along the cross fault investigated for possible neotectonic displacement, since no other sites had suitable Tg surfaces or Quaternary sediments overlying the fault zone.

The cross fault is located along a linear NE-SW-trending fault controlled valley (Figure 8a) where a remnant silcrete surface of the Grahamstown Formation (Tg) overlies bedrock of the Peninsula Formation. At this site the cross fault is positioned along the northern hillslope of the valley. During field reconnaissance the location of the fault was determined by projecting the fault controlled valley towards the hillslope below the Tg surface. The fault zone was locally confirmed by the presence of a vegetation lineament and break-in-slope along the hill slope in the valley (Figure 8a). Along an N-S-trending hillslope to the south of the NE-SW-striking valley the fault zone is capped by a thick 5 m silcrete (Figure 8c). The silcrete shows no displacement and in addition no break in slope or fault scarp is observed at the surface and therefore provides good evidence for the lack of neotectonic displacement at this site locality.

It must be noted that here the fault trace is 100m south of where it is presently mapped according to the 1:250 000-scale, 3324 Port Elizabeth geological map (South African Geological Survey 1991).
SITE LOCALITY WCCF-01

An investigation into the western Cofre fault for seismic source characterization of the proposed Thyspunt nuclear site, Eastern Cape, South Africa.

Figure 7: Site locality WCCF-01 (S33° 36' 52.1" E24° 54' 03.8""). The position of the VCCF as indicated in the figure is according to the published 1:250 000, 3324 Port Elizabeth geological map (South African Geological Survey 1995) and shown by the red line. After field investigation the fault trace can be moved 160 m east of where it is currently shown to cross the silcrete cap (Tg). (imagery from Google Earth)
Figure 8(a): A NE view of the fault controlled valley from site locality WCCF-01. The inferred location of the WCCF is indicated by a vegetation lineament and break in slope along the northern hill slope and annotated as a red dashed line in this photo. No displacement of Tertiary silcrete was observed (S33°36’54.1’’ E24°53’58.2’’). (b) Brecciated quartzite of the Peninsula Formation along the eastern hill slope (S33°36’24.6’’ E24°54’33.4’’) capped by a 5 m continuous unbroken silcrete exposure (c) at the top of the hill (S33°36’54.1’’ E24°55’56.5’’). Mapsheet 3324DB Cockscomb, farm 269, Heutskloof /Jackals Kloof.

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FIELD OBSERVATIONS AT SITE LOCALITY WCCF-01

An investigation into the Western Coega Fault for seismic source characterization of the proposed Thyspunt nuclear site, Eastern Cape, South Africa.

CGS REPORT 2012-0030  FIGURE 8(a, b, c)

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4.3.2 Primary Western Coega Fault

4.3.2.1 Site PWC-01

Site locality PWC-01 (S33°36'16.6" E24°55'21.5") is situated 400 m east of where the PWCF terminates against the Western Coega Cross Fault (Figures 9 and 10). Initially the site was studied from aerial photography and with the aid of GEP, where it appears the fault is located just south of a planed terrace surface that is not capped by silcrete (Figure 10a). In the field this site was determined to be on a bedrock planation surface situated at a lower elevation than the secondary fault which is interpreted to be formed as base level dropped and bedrock incised. On the planation surface there is a step in bedrock elevation that is infilled with fluvial deposits that have subsequently been cemented.

The incision and infilling indicates that the bedrock step is associated with a palaeo-channel margin where the bedrock was eroded along a cut bank and infilled. Lying as it does so close to the headwaters of the KwaZunga River, this geometry is expected. Further, the slope to the north of the target observation point must be seen in this geomorphological context, where in the absence of well-developed planed erosion surfaces, any slope should be viewed as part of the immature headwaters of the river system. Finding faults in such a setting is challenging due to the beveled nature of the bedrock that would eliminate out any palaeo-fault scarps. A topographic profile was positioned over the projection of the primary fault on the beveled bedrock and silcrete channel margin surface (Figure 10a & b) where no displacement was recorded in the field, as indicated (Figure 10c).

4.3.2.2 Site PWC-02

Situated roughly 1.6 km south from site PWC-01, is site PWC-02 (S33°36'29.5" E24°56'21.7"); also regarded as a low priority site; it was inaccessible during field investigations (See appendix WC2), but was observed from a remote locality, a few hundred metres away (Figure 9). This site was originally selected during airphoto interpretation because it is close to the fault and may allow for more accurate mapping and field verification of the fault.

The Grahamstown Formation is absent at this site: therefore, the possibility of neotectonic displacement could not be determined. The site did, however, provide a
valuable opportunity to constrain the locality of the PWC fault, which appears to be just south of the planed erosion surface (Figure 9). Airphoto reconnaissance confirms the likely location of the fault in bedrock.
Figure 9: A panoramic view, looking east of site localities PWC-01, 02, 03 and SWC-01 (33.3° 36' 24.6" E 24° 54’ 33.4’’).
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4.3.2.3 Site PWC03

Previously referred to as site K1.009 (Goedhart 2004), site PWC-03 (S33°36’36.2” E24°57’05.0”) is located 1.14 km south of PWC-02 (Figure 9), along the upper KwaZunga River and is one of only a few directly accessible sites. Here the PWCF, which lies within the KwaZunga River valley, is evidenced by a wide brecciated zone of deformation. The brecciated zone of Peninsula Formation quartzite is best exposed towards the west. The fault zone dips north and appears to form a conjugate set with the south-dipping secondary Western Coega Fault to the north.

Remnants of the Neogene river-terrace silcretes of the Grahamstown Formation are well developed, have good lateral continuity, cap the fault zone almost in its entirety and show no evidence of displacement by the PWCF (Figure 11a, b and c).

Site PWC-03 is one of the best localities to investigate the possibility of neotectonic reactivation, because the fault is easily identifiable in the field and is directly capped by a thick layer of silcrete.

4.3.2.4 Site PWC-04

Roughly 4 km east of site locality PWC-03, is target site PWC-04 (S33°37’18.5” E24°59’31.8”). The site was inaccessible during field investigation (See appendix WC2) and was only studied from aerial photography and observed from remote localities in the field (Figure 12).

The Tg surface is well developed at this locality, but appears at no point to be underlain by the PWC fault zone. The fault trace is mapped south of the silcrete and is exposed as a bedrock saddle in Peninsula Formation quartzite. It should be noted that no displacement of the Tg surface was observed (Figure 12).

4.3.2.5 Site PWC-05

Situated roughly 5.9 km east of PWC-04, site PWC-05 (S33°38’20.9” E 25°03’06.6”) is located just north of the Kwazunga River path. The site (Figure 6) was identified as a locality where the position of the PWCF could be verified. However, because the fault zone at this locality is not capped by Tg silcrete or any younger deposit that could be used to assess recent displacement, the site was not visited. Terraces are less well preserved from this site locality onwards, to the east along the primary fault.
The site was not visited during field reconnaissance because priority was given to sites that have a silcrete cap (Appendix WC02).

4.3.2.6 Site PWC-06

Low priority site PWC-06 (S 33°38'54.9" E 25°05'46.0"), located 4.25 km east of site PWC-05, was inaccessible during field investigation (See appendix WC2). Viewed in aerial photography it appears that the PWCF crosses a scree-slope, but offset along the slope is inconclusive. The site was reviewed by Goedhart (2004), where it was referred to as K1.010 (S 33°38'47.94" E 25°05'48.41"). See Table 2.

4.3.2.7 Site PWC-07

As is the case with site PWC-06, low priority site PWC-07 (S 33°39'32.3" E 25°09'47.6") was also inaccessible during field investigation. The area is characterized by very steep mountain ridges and deep river valleys. Studied from aerial photography the site appears to have planed surfaces with silcrete development.

The fault trace is difficult to pinpoint. Assuming the fault is correctly mapped according to the published 1: 250 000-scale, 3324 Port Elizabeth geological series (South African Geological Survey 1991), there appears to be no break in slope or silcrete displacement.
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Figure 12: A panoramic view of site locality PWC-04 (S31°33' 3.1" E24°57'33.8''). The extent of silcrete outcrop is enclosed by the yellow dashed line. The SWCF is just south of both the silcrete cap and site locality. Mapsheet 3324CA Strydomberg, farm 277, Roodplaats.

REMOTE VIEW OF SITE LOCALITY PWC-04

An investigation into the western Caequa fault for seismic source characterization of the proposed Thyspunt nuclear site, Eastern Cape, South Africa.
4.3.3 Secondary Western Coega Fault

4.3.3.1 Site SWC-01

Site SWC-01 (S33°36'06.3" E24°55'32.0") is the northernmost target area along the secondary western Coega Fault before it terminates against the WCCF. This locality, which is situated just 400 m north of site PWC-01 (Figure 13 a) is on a terrace surface slightly higher in elevation than PWC-01. Although no silcrete of the Grahamstown Formation is present, the fault crosses the abraded bedrock surface formed by river incision. The position of the fault indicated by airphoto reconnaissance was located in the field and did not appear to offset the bedrock surface. Currently the position of the SWC fault is indicated slightly to the north of the target area in the published 1: 250 000-scale 3324 Port Elizabeth geological series (Figure 13a). However finding evidence of the fault being present at this locality proved problematic and no evidence of breccia or displacement was observed.

A N-S-trending topographic profile was measured across the surface where the fault trace is projected. The profile documented the lack of a bedrock scarp, which indicates that it is unlikely any displacement along this portion of the fault has occurred since the formation of the abraded bedrock platform (Figure 13 b and c).

4.3.3.2 Site SWC-02

First investigated with the aid of aerial photography, site SWC-02 (S33°36'38.2"E24°58'30.2"), (Figure 14) was initially deemed a high priority site as it appeared to have good silcrete development on a broad planed terrace surface that showed no offset or scarp in the region of the mapped fault zone. However, field investigation showed that silcrete was almost completely absent or very poorly preserved and without adequate silcrete coverage above the fault zone, the possibility of neotectonic movement occurring at this site is therefore inconclusive.

To the east of the planed surface brecciated quartzite confirms the fault position is accurately mapped (Figure 15). There was no fault scarp identified on the abraded bedrock surface indicating the possibility of no displacement along this portion of the fault since the formation of the platform.
Figure 13: (a) Site locality SWC-01 (53°3'06.3" E24°55'32.0") is located roughly 400 m from site PWC-01. (b) Topographic profile SWC-01 was conducted across the SWCF at site SWC-01, indicated in (b) by the white line. (c) Topographic profile SWC-01 shows no scarp or offset at the surface. (Imagery from Google Earth)

An investigation into the Western Coega Fault for seismic source characterization of the proposed Thyspunt nuclear site, Eastern Cape, South Africa.
Figure 14: Site locally GWG-02 ($29^036'30.2''$ E24$^056'30.2''$). The GWG position is indicated by the red line and taken from the published 1:250 000 3324 Port Elizabeth geological series and confirmed by field investigation. Although there appears to be silcrete development across the planed terrace surface, little to no Grahamstown Formation is actually present. (Imagery from Google Earth)
Figure 15: Along the western side of the planed terrace surface, brecciated quartzite confirms the published location (1:250 000 3324 Port Elizabeth geological map) of the SWCF. At no point is the fault zone overlain by silcrete. Mapsheet 3324 DB Cockscomb, farms 275, Mierhoop Plaat, located within the Mierhoopplaat Nature Reserve.
4.3.3.3 Site SWC-03

Site SWC-03 (S33°36'57.5" E24°59'43.3") was not accessible by vehicle and therefore an attempt to reach the surface by foot was made. A 4.5 km hike along the dried river bed was undertaken in order to get to the base of the surface, however, the hike ended at the adjacent bedrock saddle directly to the west of the site locality. The surface reached by foot was a bedrock saddle where the fault could be located by a break in the slope of the saddle associated with brecciated quartzite (Figures 16 & 17). At this point the SWC-03 surface was clearly visible across the eastern drainage and the fault position could be determined from a distance. The hike across was considered too dangerous and unnecessary due to clear evidence for lack of faulting on airphotos. Further, a continuous silcrete package could be followed using binoculars along the rim of the abrasion platform indicating no offset across the fault zone in the overlying deposits (Figure 18). The fault position could be identified by change in dip of underlying bedrock units. A fault scarp was not observed at the unconformity between the bedrock and Tg silcrete.

4.3.3.4 Site locality SWC-04

Site SWC-04 (Figure 19) was not directly accessible, but was investigated with the aid of aerial photography and GEP. Located roughly 2.3 km east of SWC-03, the site (S33°37'17.3" E25°01'08.4") was primarily chosen as a locality where the fault location could be verified. The NW-SE-striking fault appears to be located directly south of a large planed terrace surface across a saddle assumed to be in the Peninsula Formation.

Silcrete to the north and south of the fault does not appear displaced when viewed from a remote location, some 2.3 km away (Figure 20), along the southern slopes of the KwaZungu River valley, looking north. No change in dip or scarps at the surface could be identified at the site.

As viewed in GEP, the fault coincides with a saddle in the ridge where the Tg silcrete and terrace have been eroded. Although this is a good indicator of the position of the fault, it is a poor location to assess recent displacement along the fault. Bedrock saddles are commonly observed geomorphological features along portions of both the primary and secondary traces of other regional faults. The saddle bedrock features are attributed to the fractured quartzite along the fault that is more easily
eroded and prone to weathering. Lack of faulting in the Tg silcrete and bedrock planation surfaces less than 2km to the east and west of this site locality at SWC-03, SWC-04 and SWC-06 further demonstrate that the bedrock saddle is an erosional feature.

4.3.3.5 Site SWC-05

Similar to site SWC-04, site locality SWC-05 (Figure 6 & 21) is also not accessible by vehicle or foot. Instead the site (S33°37'38.5" E25°01'46.8") was investigated with the aid of GEP and aerial photography. In addition the site was observed from a remote locality towards the southwest some 2.3 km away (Figure 20) from where it appears that a large planation surface is present with well-developed silcrete. The fault zone is currently mapped to cross the silcrete cap, but without direct field access this cannot be verified. It should be noted that the silcrete surface does not appear to be displaced. The resolution of the aerial imagery was sufficient to confirm what was observed in the field, therefore, there is no evidence that suggests there is a fault scarp on this surface.

4.3.3.6 Site SWC-06

This site locality (S33°37'52.7" E25°03'01.3") was previously investigated in a report by Goedhart (2004) where it was referred to as site K2.005 (Table 2). Goedhart studied the site by means of aerial photography and stated that he could not find any evidence of neotectonic displacement in this area, but additional field verification was needed.

Site SWC-06 is located roughly 1.4 km from site SWC-05 and is the most eastern locality investigated along the SWCF. The fault was identified in a series of bedrock saddles to the east (Figures 20 & 22). The south-dipping bedrock on the south side of the fault terminated rather abruptly in a zone roughly 50 metres wide underneath the Tg surface and then assumes dip to the north.

At this site the fault is covered by the largest Tg surface (in terms of surface area) in the Coega Fault corridor. In addition this location is unique because there are two distinct lobes of the planation surface that are separated by a large valley where Paleozoic bedrock is exposed. This presents the opportunity to observed four Tg edges that potentially outcrop and thus can be examined for potential offset.
Figure 16: Bedrock saddle west of site SV/C-03. The location of the fault is indicated by the red dashed line (S13°36′51.02″ E24°50′26″). Mapt sheet 3324 De Cockscomb, farm 275, Mierhoop Plaat, located within the Mierhoopplaat Nature reserve.
Figure 17. Brecciated quartzite within the Peninsula Formation (533°36'51.17" E24°59'10.85") defining the location of the SWCF, west of site locality SWC-03. The breccia displays an E-W fabric. Mapsheet 3324 DB Cockscomb, farm 279, Mierhoop Plaat, located within the Mierhooplaat Nature reserve.

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Figure 18: Looking east from bedrock saddle at SWC-03. Note the planation surface is not offset. Biconocular reconnaissance indicated a continuous planation surface and overlying silcrete with no evidence of a fault scarp. Photo taken from 33°33'36.51" S, 24°39'20.87" E, Mapsheet 33J4 DB Cockscomb, farm 275, Mierhoop Plaat, located within the Mierhoopplaat Nature reserve.

FIELD OBSERVATIONS AT
SITE LOACLITY SWC-03

An investigation into the western Coega Fault for seismic source characterization of the proposed Thyspunt nuclear site, Eastern Cape, South Africa.

CGS REPORT 2012-0030 | FIGURE 18
Figure 19: Site locality SWC-04 (53°37’7.3” E25°01’08.4”). The published (1:250 000 3324 Port Elizabeth geological map, South African Geological Survey 1981) location of the SWCF is indicated in the figure by the red NW-SE trending line. The fault position is inferred to coincide with a saddle between the two planed terrace surfaces but this could not be verified, as the site was practically inaccessible. The fault zone does not appear to be capped by a silcrete surface. (Imagery from Google Earth)
Fig. 20: A northern view across the KwaZulu River valley of site localities SWC-04, SWC-05 and SWC-06. The inferred position of the SWCF is indicated in the figure by the dashed red lines. At site SWC-04, the fault trace appears to run along saddle of Paleozoic sediments. Along this saddle it is assumed that silcrete has eroded away. Silcrete surfaces adjacent to the inferred fault zone show no change in dip, or vertical displacement. Sites SWC-05 and SWC-06 have broad silcrete development across large planed terrace surfaces. The silcrete at these sites appears unbroken. The saddle continues eastward to sites SWC-05 and SWC-06 and is therefore presumed to be a erosional feature of the less competent material representative of the fault zone. Photo was taken from location S33° 36' 7.4" E25° 00' 0.8". Mapsheet 3324CA Strydomsberg, farms 277, Roode Plaat and 278, Zwartboch Plaat.
Figure 21: A northern view of site SWC-05 (S33°37'38.5" E25°01'46.8"). The fault zone is capped by the silcretes that appears in aerial photography and GEP to show no displacement, change in dip or scarp at the surface. The SWCF trace is indicated by the red line and its position is taken from published 1:250 000, 3324 Port Elizabeth geological map (South African Geological Survey 1991). The accuracy of the fault position could not be verified, as the site is inaccessible from a practical standpoint. (Imagery from Google Earth)
Figure 22: An eastward view from site locality SWC-06 (Photo taken from S33°37' 59.5"E25°03'24.6"). The fault could not be confirmed in the field, but is interpreted to be located along the saddle between the two ridges. Note the silcrete surface in the background above the fault trace is not displaced by the fault. Mapsheet 3324CA Strydomsberg, Farm 278, Zwartbosch Plaat.

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The Tg terrace is gently south-dipping towards the river. There are three to four subtle steps in the terrace that have no offset associated with them. These are interpreted to be different terrace levels that correspond to subtle drops in base level, creating a new planation surface as the river eroded down to its present level. There is no fault scarp or discrete offset in the Tg silcrete seen in airphotos and the field observations confirm the lack of displacement (Figures 22 & 23).

Using an Abney level, 5 metre rope, and a tape; a 160m long profile was measured across the Tg surface. This was done in two segments, the original ~130 metre long profile and the later added ~30 metres north along the profile to ensure that the profile completely crossed the fault. The profile documents the lack of vertical offset observed in the field (Figures 24 a and b).

5. Dating Results

5.1 Sample Localities

Quartzite clasts from the Tg surface were sampled in the vicinity of WCF, near site locality SWC-06 as part of a cosmogenic geochronology investigation to determine tectonic stability and geomorphic evolution of not only the study area, but also as part of a larger study encompassing the greater southern Africa (Bierman 2012 – report in progress). Three samples (TSP-12A - C) were collected on the post-African I KwaZunga river surface (Table 4 & Figure 25) of which only two were analyzed.

In addition, to the west of the WCF, eight river sediment samples were collected. These samples were taken with the intent to constrain basin-averaged landscape erosion rate and thus isostatic uplift due to unroofing or removal of material.

5.2 Dating Results

The average minimum history of sample s (TSP-12) of the Grahamstown Formation situated upon the post-African I surface along the KwaZunga River, near the SWCF gives an age of 2.0 - 3.7 My. This age bracket is suggestive of a surface that has been stable near the Earth’s surface since at least the Pliocene (Bierman 2012 – report in progress). Analysis show similar ages (2.6 – 3.0 My) for Tg surfaces along the unfaulted Kouga Fault (McCalpin 2009) located southwest of the WCF.
Figure 23: Looking west the SWCF shows no displacement of the younger silcrete surface. Mapsheet 3324CA Strydomsberg, Farm 279, Zwartbosch Plaat.
Figure 24: (a) Site locality SWC-06 (53°3′S 25°5′E). Location of topographic profile SWC-06 is indicated by the thin white line. The location of the fault is indicated by the red line. The fault position is taken from the published 1:250 000, 3324 Port Elizabeth geological map South African Geological Survey (2001). Field reconnaissance verified its published position. (b) Topographic profile SWC-06. The profile documents the lack of vertical offset observed in the field. (Imagery from Google Earth)
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Table 4: Locality of cosmogenic samples taken in the vicinity of WCF (After Bierman 2012 (report in progress)).

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<tr>
<th>Sample number</th>
<th>Co-ordinates</th>
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<th>Minimum exposure (My)</th>
<th>Minimum exposure (My)</th>
<th>Minimum total history (My)</th>
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<td>Longitude</td>
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<td></td>
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<td>Western end of WCF on post-African I surface, near site locality SWC-06</td>
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<tr>
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<td>Quartzite clasts from the Grahamstown Formation were sampled</td>
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<td>1.995</td>
<td>0.099</td>
<td>2.094</td>
</tr>
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</table>
The river sediment analyzed from various south coast drainage basins, west of the WCF, indicates that the land surface is eroding at an area-weighted average of 5.4 m/My. This slow rate is consistent with tectonically stable areas around the world (Portenga and Bierman 2011). No significant correlation between the basin-scale erosion rates and physical properties of the sampled watersheds can be drawn. The lack of correlation between basin-scale erosion rates and mean basin slope is consistent with a stable base level, and therefore an absence of differential uplift (Bierman 2012). Dating results show a slow uplift rate for both the KwaZunga and Kouga drainage basins and thus a tectonically stable crust. This result is consistent with field observations that showed no conclusive evidence of neotectonic displacement along the WCF.

The Sundays River valley, located south-east of the WCF also shows similar low erosional rates of 6.62 ± 1.1 m/My (Erlanger 2010). Such slow erosion rates, coupled with the Pleistocene age of the Tg surface, would suggest that if fault scarps were formed, they would still be visible in the landscape today. Thus the absence of scarps or offset along the WCF is indicative of an inactive fault since Pleistocene times (Bierman 2012).

6. Conclusions

Investigation into the possibility of neotectonic displacement along the WCF was conducted with the aid of a desktop study that included a review of previous studies undertaken in the area, and an additional review of the area’s aerial photography and satellite images provided by GEP. Based on the desktop review several sites were selected for further detailed investigation by means of a field reconnaissance. The primary focus was to select and sites for any displacement of erosion surfaces, known as the Grahamstown Formation (Tg) or Quaternary sediments in places where they overlie the fault trace.

Three sections of the WCF were investigated; the WCCF, PWCF and SWCF. The WCCF has a very short length, dissimilar strike to the NW-SE trending Kango Fault and along a number of points along its length displays evidence of a lack of displacement of the Neogene Tg surface and deposits. In addition, no evidence for Pliocene or Quaternary displacements or fault scarps were observed along its trace.
Based on the field evidence collected and cosomogenic results (Bierman 2012) that show a lack of evidence suggestive of neotectonic activity in the last 2-3.7 My, or at least since the Pleistocene, coupled with the slow erosion rates of 5.4m/My, the area that houses the WCF occurs within a tectonically stable landscape. Such slow erosion rates, coupled with the Pleistocene age of the Tg surface, suggests that if fault scarps were formed, they would still be visible in the landscape today. Thus the absence of scarps or displacement along the WCF is indicative of an inactive fault since at least the Pleistocene times (Bierman 2012).
7. Acknowledgements

The authors would like to thank farmers in the study area for allowing field team access to their properties. Without their co-operation this report would not have been possible.

In addition the authors would also like to thank the following people:

Erna Hattingh and Johann Neveling from the Council for Geoscience for their technical and administrative support during the project and final report writing stages. Their dedication is very much appreciated.

Taufeeq Dhansay from the Council for Geoscience for his willingness and enthusiasm during field reconnaissance. His data collection and field observations greatly assisted in the site investigations.

Coenie de Beer from the Western Cape Unit of the Council for Geoscience for his willingness to accompany Dr. Koos Reddering to the study area and valuable discussions regarding field observations at selected sites.

Kathryn Hanson from AMEC E&I,Inc. (formerly AMEC Geomatrix, Inc.) for her valuable suggestions with regard to this report's structure, format and scientific content and her always enthusiastic approach to the work.
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Appendix WC01
Comparison between Viewing Stereoscopic Aerial Photographs and Google Earth Pro Images to Carry Out Terrain Analysis with the Aim of Geological Selection of Potential Fault Reactivation
Investigation into the western Coega Fault, commenced with a desktop-study phase in November 2010. A review of the study area’s aerial photographs, including those reviewed initially by the Goedhart (2004) study was undertaken before field reconnaissance. In addition it was thought prudent to view the same areas on Google Earth Pro (GEP) to see whether any advantages could be gained by the latter technique.

The following factors (Table 1) were considered in the comparison between the two techniques of studying an area’s aerial photography with the aid of a stereoscope and with the aid of the software program Google Earth/Pro:

- **Resolution**

  In Google Earth most land areas are covered in satellite imagery with a resolution of 15 m per pixel. This base imagery is 30m multispectral Landsat which is pansharpened with the 15m [panchromatic] Landsat imagery (http://en.wikipedia.org/wiki/Google_Earth#Imagery_resolution_and_accuracy). The scale of the aerial photographs (Job 622 of 1969) used in the TSHA project has a base scale of 1:36 000, the largest scale of aerial photographs. At a smaller scale of aerial photography, the resolution would degrade earlier during progressive magnification, or in practical terms, small geological features would be less resolvable. Colour-film aerial photography is also of very poor resolution compared to black-and-white aerial photographs (Reddering, 2009). As one enlarges the comparative images of the aerial photographs and GE, the latter’s resolution advantage become more apparent (Figure 1 and 2).

  No comparison was made with the modern digitally recorded aerial photographs because these images did not exist at the start of this phase of the TSHA.

**Table WC01-1: Factors to consider when choosing to use either aerial photography or GE in a geological investigation.** When considering each factor, GE was always the preferred method for use.

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<thead>
<tr>
<th>Factors for consideration</th>
<th>Aerial photography</th>
<th>Google Earth (Pro)</th>
</tr>
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<tbody>
<tr>
<td>Resolution</td>
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<tr>
<td>Derived data</td>
<td></td>
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<tr>
<td>Processing</td>
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<td>3D Viewing</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Weather conditions</td>
<td></td>
<td>X</td>
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<tr>
<td>Convenience</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Figure WC01-1: By enlarging a section of the image on 1 by 3.18x (or 7.95x the original aerial photograph), its resolution has decreased dramatically, whereas that of the GE has remained crisp, focused, and has the advantage of colour. Increasing the contrast and sharpness of the aerial photograph by digital editing cannot provide detail that was not originally recorded on the aerial photograph.

Figure WC01-2: By the time that the aerial photograph is enlarged to 5.5x (or 13.8x the size of the aerial photograph), little detail can be resolved whereas the same-size GE image is sharp. In the GE image on the left it is possible to resolve a fence and individual boulders are visible.
• Derived data
In this context; derived data refers to information the investigator can extract directly from the imagery without calculation. With GE/GEP the investigator can instantly ascertain direction, scale of view, location and length of a landscape feature or distances between features. With aerial photography the user is able to extract the same information, but through a much more tedious process. The process involves the time consuming transfer of areas of interest to a topographic map from where the calculation of distance, scale and direction would be possible. The latter method is open to much error.

In a comparison between GE and aerial photography in the acquisition of derived data, GE has proved to be far more superior.

• Location
When utilizing aerial photography the investigator has no direct indication of position (longitude/latitude) or a co-ordination reference grid. The investigator must try and find the same location of a landscape feature on a topographic map and determine the co-ordinates that way.

GE provides instant positional information as well as the opportunity for the capture and storage of locations in a ‘placemark’, a huge advantage over studies undertaken with aerial photography. GE saves a great deal of time and eliminates the possibility of error to a greater degree. Co-ordinates of site localities were easily uploaded into a GPS for field reconnaissance to the Western Coega Fault.

• Processing
In the past investigates made annotations about observations of the landscape either directly on aerial photography or on transparent overlay. As mentioned before these annotations had to be transferred to a topographic map. GE eliminates this process, which thereby reduces work time and the potential for error greatly. With GE annotation can be done with potential accuracy and stored with additional notes for instant use in the future.

• 3D Viewing
An important feature of stereoscopic aerial photography is the three-dimensional perspective it gives of a study area when viewed correctly through a stereoscope. GE system also produces a 3-D perspective, which is far more effective, with easy
titling and rotating, which is far quicker than the repositioning and rotating of aerial photography under a stereoscope.

- Weather conditions
Aerial photos are usually taken on clear, sunny days with no cloud cover by the camera mounted on the airplane. Images like those used in GE are taken from a satellite on a predestinated date, irrespective of weather, which means that cloud cover is often present, obscuring landscape view. This was the case with the 2005 GE imagery where cloud cover partial obstructed view of areas near the western Coega Fault (Figure 3a). However GE provides the user with imagery taken from a variety of different years and selecting a different date in most cases will produce a better image for viewing (Figure 3b).

![Images of GE imagery](image)

Figure WC01-3: The 2005 GE imagery showing cloud cover and obscuring the landscape and portions of the Western Coega Fault (indicated by the red line). (b) The much clearer 2010 GE imagery showing no cloud cover and depicting the landscape in full, not obscured view.

- Convenience
The convenience of GE is undeniable, a holistic approach to identifying, annotating and storage of information in a single software package. The imagery is immediately available (provided an internet connection is available) and don’t need to be ordered or searched for. No stereoscope is needed to view images in GE and the 3D perspective of view is less straining on the eyes.
Considering the advantages of identifying geological features on *Google Earth* or even better *Google Earth Pro*, it made little sense to continue using aerial photographs for this purpose. The work was done at a fraction of the time typically taken to study aerial photographs.
Appendix WC02
Routes to Accessible Field Sites in the Western Coega Fault Zone as Part of
the Investigation into the TSHA
This appendix provides the routes and land owner contact details for all the accessible sites in the WCFZ. Table WC02-1 gives the coordinates of the sites, property particulars, owners and contact details, the public-road access, turn-off coordinates and applicable descriptions. The turn-off coordinates correspond to the ‘primary intersection’ on the following diagrams on Google Earth track plots. The captions provide detailed route targets to be followed in the field for each site. It is advisable for this purpose to use a field GPS (not the vehicle-type GPS), so the target points can be entered in advance. This will allow the user to traverse directly to the navigation points and know in the field that he/she is on the right track, whether by vehicle or on foot.

All routes require suitably equipped 4x4 vehicles, which must have a low-range gear option, appropriate off-road tyres, a second spare tyre, emergency recovery kit and must be driven by confident, suitably trained and experienced 4x4 drivers. DO NOT TAKE THESE ROUTES LIGHTLY!

Although cellular-telephone reception is locally present on higher-lying ground, it is not in the valleys, so take a satellite telephone for safety. Also take an additional portable first-aid kit that can be taken along on the hikes and make sure that an appropriate snake-bite kit is present. While hiking, beware of Aardvark burrows, commonly hidden below ground-cover vegetation; these holes can cause nasty falls and even leg fractures. Wherever you stop to continue on foot, lock the vehicle with all windows closed so no animals can enter the vehicle during your absence. During off-road traverses, close all gates you find closed immediately after passing through and leave those you find open; gates act as livestock valves and you don’t know the land-owner’s intentions. Gates may be open one day and closed the next; leave them as you find them.

The areas described below are totally deserted, and you cannot pop in at the nearest house for help, so make sure that you inform someone responsible of your whereabouts and plan in advance what to do in case of an emergency.
The downloaded document is uncontrolled; therefore the user must ensure that it conforms to the authorised database version

**Table WC02-1 – Localities of accessible potential fault-reactivation sites and navigation aids for getting there.**

<table>
<thead>
<tr>
<th>Site</th>
<th>South</th>
<th>East</th>
<th>South</th>
<th>East</th>
<th>1:50 000 map sheet and Property name</th>
<th>Owner</th>
<th>Telephone number</th>
<th>Main access route</th>
<th>Primary route</th>
<th>Turn off E</th>
<th>Google Earth track image</th>
<th>Description</th>
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<tbody>
<tr>
<td>PWC01</td>
<td>-33.601590</td>
<td>24.925263</td>
<td>S33°39'16.6&quot;</td>
<td>E24°55'21.5&quot;</td>
<td>&quot;Goulde&quot; Welgevonden 16B, Zungah 274</td>
<td>M WP van Schalkwyk</td>
<td>027494763 and 0414535400</td>
<td>Unnamed</td>
<td>S23°31'52.1&quot;</td>
<td>E25°00'19.8&quot;</td>
<td>Fig. AW2C.1</td>
<td>See caption to Fig. AW2C.1 for route target coordinates</td>
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<tr>
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<td>S23°31'52.1&quot;</td>
<td>E25°00'19.8&quot;</td>
<td>Fig. AW2C.1</td>
<td>See caption to Fig. AW2C.1 for route target coordinates</td>
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<td>24.961300</td>
<td>S33°39'36.2&quot;</td>
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<td>See caption to Fig. AW2C.1 for route target coordinates</td>
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<td>E25°00'19.8&quot;</td>
<td>Fig. AW2C.1</td>
<td>See caption to Fig. AW2C.1 for route target coordinates</td>
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<td>Fig. AW2C.1</td>
<td>See caption to Fig. AW2C.1 for route target coordinates</td>
</tr>
</tbody>
</table>

WC02 - 3
Figure WC02-2 – Access to points PWC-01 and SWC-01: After getting appropriate permission from the property owner and access to keys, travel to the primary intersection (S33°31′52.1″ E25°00′19.8″) and turn south, travel to S33°32′43.6″ E 24°56′53.8″ and turn south (left). Continue past the intersection at S33°34′24.3″ E24°56′7.7″ and keep heading south through the pass, up and over the mountain. At S33°35′13.7″ E24°55′46.1″ it’s decision time. If you have traveled in two 4x4 vehicles it might be worth a chance to continue along the track, all the way to near the sites SWC-01 and PWC-01 by vehicle. If in a single vehicle, it might be prudent to park at the top of the hill and walk to the sites because no help will be able to reach you if anything goes awry. If you walk, be aware that this is very difficult terrain and especially the walk back is very taxing; do not be fooled by the mere 6 km round trip. Do not attempt this trip if you doubt your fitness. Take enough water, at least 2ℓ per person, more on hot day, and walk to the targets. Return in the opposite direction and remember to return the keys.
Figure WC02-2 – Access to points PWC-03 and SWC-02: After getting appropriate permission from the property owner, travel to the primary intersection (S33°38'29.7" E24°56'32.3"), travel to S33°38'28.3" E24°56'51.6") and turn north (left) through the gate. Keep the GPS switched on to record a track, so that it can be followed on the way back. At S33°37'18.9" E24°57’20.6” there appears to be a track leading west. Ignore this, it is a pipeline. Continue north on the track. Travel to about S33°36'40.5" E24°57’46.0” and park in the shade.

To go to PWC-03 cross the creek, actually the upper KwaZunga River and head west to [S33°36'37.2" E24°57'30.3"] and walk up the hill there instead of as shown on the map above; it is a far easier and less dangerous track than the one shown. Then follow any route along the terrace to PWC-03.

To go from the parked vehicle to SWC-02, take more or less any route to [S33°36'42.0" E24°58'6.4"] and from there walk up the slope to ]S33°36'48.2" E24°58'22.1"] to get to the southern end of the silcrete-capped terrace. From there traverse to SWC-02.
Figure WC02-3 – Access to points PWC-04 and SWC-03: After getting appropriate permissions from the property owner, travel to the primary intersection (S33°38’29.7" E24°56’32.3"), travel to S33°38’28.3" E24°56’51.6" and turn north (left) through the gate. At S33°37’18.9" E24°57’20.6" there appears to be a track leading west. Ignore this, it is a pipeline. Continue north on the track. Travel to about S33°36’40.5" E24°57’46.0" and park.

From the vehicle walk eastward along the course of the KwaZungu River to S33°37’14.7" E24°59’11.7"; this not the route shown above because that was taken along the wrong hill and a knee injury to one prevented the authors to go to the correct hill. From the river level traverse up the hill spur to S33°37’10.0" E24°59’26.10". From there both sites PWC-04 and SWC-03 can be reached by walking along the terrace surface.
Figure WC02-4 – Access to points SWC-06 and possibly PWC-05: After getting appropriate permissions from the property owner, travel to the primary intersection (S33°32'32.8" E25°07'10.4"), turn south and travel along the dirt track to S33°33'47.9" E25° 4'45.2". There turn south (left) and follow the track across the mountain to SWC-06. Although the authors didn’t follow it, the track continues to near PWC-05, and it may be possible to drive or walk there from the edge of the terrace edge-break, it is less than 1km each way.

Figure WC02-5 – Access to points WCCF01: After getting appropriate permissions from the property owner, travel to the primary intersection (S33°37'38.0" E24°53'43.3"), turn north and travel along the dirt track to S33°37'34.8" E24°53'43.0", turn right, cross the creek and follow the upper track into the valley to the north and stop at S33°36'52.1" E24°54'3.9" for the site visit.
### Koos Reddering

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<thead>
<tr>
<th>WP</th>
<th>Sheet</th>
<th>Field book</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Image</th>
<th>Field description</th>
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<td>3325CC</td>
<td>7 33 45</td>
<td>13.1</td>
<td>25 6 19.4</td>
<td></td>
<td>2010-11-14, GPSWP38 - Start of the scouting trip for access routes. No need to calibrate the equipment because the day was set aside to determine access routes to the places of interest for investigation, and to prepare a list of potential access routes. Note: We proceeded to the western limit of the mapped fault (western Coega) and turned back along the Elands River Valley, scouting for tracks leading north into the mountains, property owners, and telephone numbers, where indicated. It being Sunday, we made no contact with the land owners. The waypoints will proceed eastward.</td>
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<td>KWC02</td>
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<td>7 33 37 41.8</td>
<td>24 53 20.9</td>
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<td>2010-11-14, GPSWP39 - Middelwater, tel 079 898 9504 or 082 903 0938</td>
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<td>8 33 37 38.0</td>
<td>24 53 44.3</td>
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<td></td>
<td>2010-11-14, GPSWP40 - Track leads northward to the cross-fault at the western end of the Coega Fault. Need to get to this one! [Tel later obtained for owner, Sydney Scheepers, 082 771 9325.]</td>
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<td>8 33 37 54.0</td>
<td>24 54 31.2</td>
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<td>2010-11-14, GPSWP41 - Possible site with track to the north but KWC03 is the preferred option. No telephone number.</td>
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<td>24 56 2.7</td>
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<td>2010-11-14, GPSWP42 - Farm house, little prospect. No telephone number.</td>
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<td>24 56 31.7</td>
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<td></td>
<td>2010-11-14, GPSWP43 - Wheatlands, promising route northwards. [Owner of Rose Cottage, Sarel van Deventer 083 621 9188]</td>
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<td></td>
<td>2010-11-14, GPSWP44 - Good track leading north into the fault area. No telephone number</td>
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<td>2010-11-14, No GPSWP recorded but value written down in notebook - Kwa-Zunga Bush Camp. Route appears to head right into the mountains to the north. [Later inspection revealed a locked gate along the route with no contact details.]</td>
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<tr>
<td>KWC10</td>
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<td>9 33 42 7.9</td>
<td>25 1 59.2</td>
<td></td>
<td></td>
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<td>3324CA</td>
<td>9 33 43 19.1</td>
<td>24 5 37.6</td>
<td></td>
<td></td>
<td>2010-11-14, GPSWP46- Turn-off to 4x4 trails (have to pay?) [No]</td>
</tr>
</tbody>
</table>
2010-11-15, GPSWP47- Obtained permission from the owner, Mr Sydney Scheepers to access the property. This site is at the top of a hill, and Ryan and I thought that the site is better than the one mapped, based on lithology, valley straightness and image texture on Google Earth Pro. There is brecciated quartzite up the hill slope where we proposed the hypothetical fault. At the top of the hill there is continuous and unbroken silcrete of the Grahamstown Formation (Kg). Ryan intended running a Trimble traverse but the instrument didn't work (subsequent thought was that it needed more time to establish high-level contact with the GPS satellites), and owing to the uncertainty of the position of the fault. The silcrete is continuous, without break and slopes gently southward towards the Elands River Valley. There appears to be a change in lithology across the valley to the NE but it appears to be a function of steeply-sloping north-facing valley sides and gentler south-facing sides rather than rock type(see image iKWC12a) iKWC12a - The valley along which the fault probably extends more likely than where mapped by Toerien; note the steeply north-facing slopes exposing more bedrock than the gently southward-sloping hill sides.

iKWC12b iKWC12B - Edge of the silcrete at the top of the hill.

KWC13 3324DB 11 33 36 53.1 24 53 58.2 iKWC13a 2010-11-15, GPSWP48- Breccia in the inferred position of the fault

iKWC13b iKWC13b - The linear depression down the hill slope along the inferred new position of the fault with breccia-bearing erosion channel in the foreground lines up with the vegetation line in the hill beyond. This fault position remains speculative.

iKWC13c iKWC13c - More breccia in the inferred fault position.

KWC14 3324DB 11 33 36 24.6 24 54 33.4 iKWC14 2010-11-15, GPSWP49- iKWC14 - View across towards PWC01 as a panoramic view.

Contacts made not recorded as waypoints: Klipkraal; Mr Ivan Ferreira tel 072 425 6922. De Fonteine Resort, Messrs Jan Werkman, 018 294 3902 & Jacques Claassen 082 829 8325. Donovan Whitehead at the 4x4 site, who referred us to a neighbour Mr Thomas Pitchman tel 079 527 2691. Mr Sarel van Deventer of Rose Cottage 083 621 9188.

KWC15 3325CA 12 33 38 7.4 25 0 0.8 iKWC15a,pano 2010-11-16, GPSWP50- We were denied unaccompanied access to the farm Rose Cottage by Mr van Deventer; he is concerned about his cycads, and about reports that geologists entered farms in the Stilbaai area on false pretences. So we relocated to De Fonteine, where the faults could not be reached, also not by extending onto Mr Ferreira’s land. Two panoramas were photographed for reference. iKWC15a,pano - Panorama of the silcrete erosion surfaces on the northern side of the Kwazungu River.

iKWC15b,pano iKWC15b,pano - Panorama of the silcrete erosion surfaces on the northern side of the Kwazungu River. Duplicate of iKWC15a,pano. (Duplicate taken to avoid having incomplete image data.) Use this one if necessary.
Access to this point was not practical from the Elands River side and we eventually, after scouting, obtained permission from Mr Willie Lloyd (tel, 079 896 8878) to approach from the north, with access from the Uitenhage - Steytlerville dirt road and driving a category 5 4x4 route. Viewpoint overlooking where the secondary Western Coega Fault appears on the geological map. iKwc16a - Westward view of the valley slop where the SWC fault is mapped. Patchy silcrete is present at the top of the valley side. The fault is not clearly evident.

iKwc16b - Eastward view from this point. The saddle along the ridge with the dark vegetation at the back is the most likely site of the SWC fault trace.

iKwc16c, pano - First of two panoramic views of the fault zone

iKwc16d, pano - This second panorama covers more ground. Use it if necessary.

Start of topographic section line across the Secondary Western Coega Fault. Calibrated Abney level. [The section was to have been measured by a Trimble GPS, but this did not work because the instrument had insufficient contact with GPS satellites. So the decision was taken to measure it using a Jacob's Staff, i.e., an Abney level mounted on a vertical staff, in this case a photographic monopod. Elevation was measured by using a measuring tape with a cable tie at the zero end so that it could firmly be held on the ground by standing on the cable tie. The 'chain' was a 5m length of braided polypropylene rope to keep foresight and backsight readings at the same distance, thus eliminating systematic calibration errors (calibration of an Abney level is not exact). In this way a 170m-long section was measured across the projected position of the fault.] This waypoint is the first Jacob's Staff position in the section.

At this view across a short valley there is a step in the silcrete, younging southward towards the Kwazungu River. It is in the wrong place to be a fault displacement. iKWC19 - Two different terrace-silcrete levels.

Restart of the topographic section. Although the original probably contained the underlying fault trace, it was extended by 30m to make sure.

End of the topographic profile between KWC17 and here. The recalculated section data given as distance, elevation pairs are: 0, 0; 10, 0.69; 20, 1.64; 30, 2.67; 40, 3.53; 50, 4.21; 60, 4.89; 70, 5.57; 80, 6.13; 90, 6.40; 100, 7.14; 110, 7.32; 120, 7.88; 130, 8.44; 140, 8.86; 150, 9.28; 160, 9.85; 170, 10.06.
The downloaded document is uncontrolled; therefore the user must ensure that it conforms to the authorised database version

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<td>2011-02-22 A view of the silcrete section overlying the mapped fault initially indicated at K1.009. No fault is evident from the site through binoculars but a very distinct change of bedding dip is evident (later identified as structural fabric, not bedding) to the south of where silcrete ends. iKWC22a - Image of the southern extent of the silcrete cap. Fault? If it is it wouldn't have intersected the silcrete.</td>
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<td>2011-02-22 Brecciated quartzite prominent here.</td>
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<th>36</th>
<th>37.6</th>
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<th>10.6</th>
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<td>2011-02-22 Western edge of the brecciation zone.</td>
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<td>2011-02-22 The southernmost breccia extends 16.5m south of the silcrete cap edge, differently 16.5m of breccia is not capped by silcrete. This truncated silcrete extent cannot therefore be used to determine the presence or not of neotectonic faulting in the Palaeozoic rocks across the southernmost 16.5m.</td>
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<td>2011-02-22 iKWC26 - Northward view of the silcrete at the top of the terrace.</td>
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<td>2011-02-22 iKWC27 - Breccia with scale overlain by silcrete in the background.</td>
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<td>2011-02-22 iKWC28 - This view along the silcrete horizon shows that it is unbroken at the above where the shear in the Palaeozoic bedrock below line intersects the silcrete. There is a vertical discontinuity, i.e., no inference possible there, but the silcrete to the south displays continuous bedding. A small collapse structure has caused a small depression in the silcrete.</td>
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<td></td>
<td>2011-02-22 The inferred fault shown on the map at this point is present but no silcrete is present here. iKWC29 - Sheared quartzite in the fault zone indicated on the map. No silcrete present here.</td>
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<td>2011-02-22 iKWC30 - Intersected the primary fault in the river bed.</td>
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<table>
<thead>
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<td></td>
<td>2011-02-23 iKWC31 - View from a higher vantage point across the silcrete terrace to be visited.</td>
</tr>
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</table>

Note: The straight line shown on my exploratory Google Earth map as a possible fault, it is in fact a fence line. We didn't visit the site but the fault is present in the area as a broad fault zone and not a sharp line. There is a fence there.
2011-02-23 Faulted quartzite with foliated breccia is present here but no capping silcrete near the edge of the hill-top terrace. **KWC32 - Brecciated quartzite at the edge of the hill slope but no silcrete. Breccia extends to Taufeq.**

2011-02-23 The site marked by Ryan Coppersmith as SWC-02. Nothing special here, only vegetated soil but no silcrete. But from 31m north, i.e., into the image, the ground rises to form a gentle scarp that extends to the towards a slope change to flat ground above; there is no silcrete there, much like the situation at the first terrace to the west (KWC26 to KWC29), where silcrete also pinches out northward. The silcrete appears in section to abut this gentle scarp, which most likely represents a palaeo-cut bank in the ancient river profile. Since no silcrete is present it serves no purpose to measure a topographic profile. **iKWC33 - The gentle scarp separating the two terrace levels.**

2011-02-23 Traversed from KWC33 to the top of the gentle scarp and then eastward along the strike of the ridge to the edge of the platform where brecciated quartzite is present but no silcrete. So little or no silcrete is present at either end of the gentle scarp, between KWC32 and this waypoint, and to the north of the line between these waypoints.

2011-02-23 A small patch of surface silcrete.

2011-02-23 View of the terrace from the SWS, across the KwaZunga River valley. The silcrete is developed only on the southern extent of the terrace from the arrow (on iKWC36,ann) to the south, (right). Underneath the arrow lies the almost imperceptible gentle scarp, to the north of which the development of silcrete is very patchy/non-existent, and the erosion surface is exposed in truncated Palaeozoic quartzite. A similar succession is evident on the eastern exposure of the terrace. The southward gently-grading slope cutting east-west across the even more gently sloping terrace system is probably a palaeo-cut bank developed by the palaeo-KwaZunga River as the erosional base level fell gently as part of the development of the post-African I erosion surface, preceding the aggressive incision that produced the deeply incised river and tributaries now evident.

**Note2011-02-23** The silcrete extends only along the southern region of the overall terrace, and is covered by soil but totally smooth. It lies south of a gently inclined surface that arose, probably, as a cutbank feature cut into Palaeozoic bedrock. The Palaeozoic quartzite is brecciated along the entire edge of the erosion scarp, both on its western and eastern edges, and no specific fault zone is discernable. Taufeq Dhansay has concluded that the brecciation took place during dome folding predating the the extentional history of the site. There appears not to have been neotectonic displacement of the silcrete in the area that it is exposed, and no clearly defined fault or fault zone. So the exposures are generally inconclusive and show no evidence of silcrete displacement. See oversight-review notes of 2011-03-10 below for an expanded explanation.
<table>
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<th>iKWC 37</th>
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</thead>
</table>

2011-02-24 First stop in the zone where no faults are currently mapped between the Baviaanskloof and Western Coega Fault systems. This site provides a view across some distant exposures in the "gap" area. No faulting is evident anywhere by inspection through binoculars. Some south-sloping silcrete terraces are present in the landscape too. iKWC 37 - View of the landscape showing no convincing faulting. Note the silcrete terraces.

<table>
<thead>
<tr>
<th>KWC38</th>
<th>3324DB</th>
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<th>24</th>
<th>48</th>
<th>42.1</th>
<th>iKWC 38</th>
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</table>

2011-02-24 Some exposures in the hill slope show that the bedding is consistently conformable. According to Taufeeq an abrupt change in bedding is evident south of here but I don't see it. It should be viewed on Google Earth to assess its potential as a fault. iKWC38 - Mosaic of the view showing the hillslope exposures; no convincing evidence of faulting is apparent.

**Note 2011-02-24:** The visit to the area between the western Coega and the Baviaanskloof faults, where no faults are currently mapped, was undertaken to see whether any step faults are present there. The rationale for this investigation is that currently mapped faults show favourable conditions for such step faults. Already there are two parallel east-west-striking faults on the western Coega system, truncated in the west southwest-northeast-striking cross fault. Also a dogleg shown in the trace of the eastern Coega fault near the coast was recently shown using geophysical means to consist of step faults in a mirror image of that hypothesised at the western end of the fault, that in question here. Unfortunately the exposure in the area of the gap between the western Coega and Baviaanskloof fault is too poor to establish the presence of step and cross faults during a one-day excursion. The underlying hypothesis, however, remains. Faults would not clearly be discernable in the poorly exposed bedrock of the target area. That does not mean that they don't exist and this question shouldn't be ignored. If it cannot be addressed in the short term it should be looked at in the medium term by 1:10 000-scale fault-strip mapping and/or geophysical investigation. The significance is that the Baviaanskloof would effectively become substantially longer if step and cross folds connect it to the Coega Fault changing the interpretation of faults in the TNSP investigation.
Notes 2011-03-10: Oversight review. The place of observation is at a site earlier indicated as PWC-03 (previously K1,009) at S33°36'37" E14°57'06", which is in the western Coega Fault corridor in the upper KwaZunga River, and previously investigated by myself and Taufeeq Dhansay on 2011-02-22. The site is one where Neogene river-terrace silcrete of the Grahamstown Formation caps the fault zone and any post-diagenetic displacement of the silcrete could indicate Neogene reactivation of the Early Cretaceous fault. Most of the additional observations were made by Coenie de Beer: 1. Our basic observation at the site was sound, i.e., that a wide, breciated zone of deformation is present, and that it follows the KwaZunga valley, or more correctly, the KwaZunga valley follows the primary fault. 2. Where the fault is overlain by silcrete, no observable displacement of this Neogene cap rock is evident and was confirmed during the field visit. 3. The so-called ‘shear’ zone at point KWC28 it is resistant bedding that was rotated during faulting, coming to rest parallel to the fault movement, which is near the shear zone but isn’t it. 4. It is probable that the fault zone is an anastomosing fracture zone with remnants (or lozenges) of bedrock remained fairly intact, surrounded by fault breccia. 5. The main fault zone, dipping north appears to be a conjugate set with that to the north, which dips south. 6. The situation is very similar to that at SWC02, where a broad breccia zone is also evident, but there is associated with the secondary fault.

KWC39 3324DB 30 33 36 33 24 57 24.6 iKWC39 2011-03-10 iKWC39 - Glacial folds at the top of the Peninsula Formation on the opposite hill slope.

KWC40 3324DB 30 33 36 31 24 57 22.7 iKWC40 2011-03-10 iKWC40 - Cut bank in the modern KwaZunga River and the palaeo-equivalent in the hill in the background (SWC02)

KWC41 3324DB 31 33 32 52 24 57 48.1

Notes 2011-04-07: Heavy rain on the day in the Elands River valley not recorded in notebook. So Ryan Coppersmith and myself drive around to find routes into the KwaZunga valley from north of the Great Winterhoek Mountains. At KWC41 we came across a locked gate that stopped further progress at ‘Oulande’ owned by Mr WP van Schalkwyk (tel nos 082 7494763 & 041 4535400). Another entry from the main road was reported by a neighbour to be that of Dr Claassen, a dentist from Despatch but no contact numbers.

KWC42 3324DB 31 33 37 3.1 24 57 33.8 iKWC42 a&b 2011-04-08 Sites identified for access from Rose Cottage were PWC04 (S33°37'18.5" E24°59'31.8"), SWC03 (S33°36'57.5" E24°59'43.3"), Access point up the hill (S33°37'15.5" E24°59'12.5"), the new owner since our previous visit was Mr Francois Nysschen (tel 082 8282475) and he granted permission by telephone. iKWC42 a&b - Two images of the target image for the day
2011-04-08 Climbed the wrong hill up to this point through wrong identification of the starting point at the bottom. We'd have to climb down and up again. [After writing this we decided to see whether a route could be gained across the top at the head of the terrace ...]

2011-04-08 Got this far after having taken a heavy fall, landing on my chin (small abrasion) and left knee. Knee bandaged - had to turn back. I needed to call it a day; the knee is injured. iKWC44 a&b bandaged knee.

2011-04-08 Two panoramic views showing the opposite valley side with the secondary fault going up the hill slope and intersecting the silcrete cap without displacement. This lack of displacement was confirmed by Ryan Coppersmith using my Nikon 7x35 binoculars.

2011-04-09 Trip to the Kwazunga valley from the Steytlerville road

2011-04-09 The African Surface, capped by silcrete, high up the northern flank of the Groot Winterhoek Mountain

2011-04-09 The African Surface with silcrete exposed in different parts of the landscape.

2011-04-09 Wide-angle pano of the Kwazunga valley showing the African Surface to the north and post-African surface above the valley

2011-04-09 Misled by my GPS again so so we landed on the wrong spur but gives a good side view of the target. iKWC48pano - Panorama of the hillside that contains PWC01 (near the orange exposure) and SWC01

2011-04-09 At point SWC01, the westernmost target of the secondary Western Coega Fault, there is no fault displacement to be seen in the field and no breccia in the bedrock windows exposed on the grassy slope, so the fault is not at the point where it was originally mapped. There is no silcrete in the vicinity. Ryan Coppersmith measured a Trimble transect across the surface to see whether anything geomorphological shows up. iKWC49pano - A view of the post-African surface in the Kwazunga valley to the east of the waypoint.
Target point PWC01, the westernmost target of the primary Western Coega Fault, at this waypoint lies below a large slope which doesn't appear to be a scarp. It is more probably an incised channel section, lying as it does so close to the headwaters of the KwaZunga River. Silcrete is present about 30m south of here but shows no displacement. iKWC50pano - A panoramic view (from private collection) shows the upper reaches of the KwaZunga River to the west of the waypoint. In contrast to the view to the east (iKWC49pano), there is no planation surface evident. The skyline all round also represents the western watershed of the river. The slope to the north of the target observation point must be seen in this geomorphological context; in the absence of well-developed planed erosion surfaces any slope should be viewed as part of the immature headwaters of the river system. Finding faults in such a setting, especially displaying potential neotectonic reactivation is fraught with uncertainty.
Appendix WC04