A re-interpretation of the active faulting in central Mongolia: supplemental data

A1 Description of the Bayanhongor fault

The NW-SE Bayan Hongor fault is formed from several sub-parallel segments all showing a clear vertical component of slip (Fig. A2a). It has been interpreted both as a thrust (Baljinnyam etal 1993) and a normal fault (Cunningham, 2001). The sense of slip on the Bayan Hongor fault has major implications for the interpretation of active faulting in the Hangay as it is one of the few known faults with a NW-SE trend. As such, if it is a normal fault, it cannot be compatible with the regional east-west left-lateral shear.

Each strand of the Bayan Hongor fault zone has a clear northeast-facing scarp up to ~600 m high (Fig. A2a,b,c). Uplift on the fault has affected drainage systems flowing southward down the flank of the Hangay mountains. Ponded drainage has formed lakes along the fault scarp (Cunningham, 2001). Defeated river channels are preserved as dry valleys within the uplifted mountains (shown as stars on Fig. A2a). Subsidence in the adjacent Bayan Hongor basin is minor with no more than 150 m of sediment deposited within it (Devyatkin, 1975; Baljinnyam etal 1993). The total vertical fault movement is therefore less than 1 km, with a ratio between uplift and subsidence of 4:1. When faults move, the deflection of the hanging-wall side of the fault is always greater than that of the footwall (e.g. Stein and King, 1984). The 4:1 ratio between uplift and subsidence at Bayan Hongor is hence strongly suggestive of thrust faulting, as the southern, uplifted, side of the fault must be the hanging-wall.

We found limited field evidence of thrusting on the Bayan Hongor fault. Southwest-dipping schists are exposed along large sections of the fault scarp (Fig. A2d). South-dipping faults were found in schists exposed in the scarp at 46:37:47N 99:54:36E and 46:46:01N 99:26:56E (e.g. Fig. 3e). We were unable to find evidence for recent activity on these south-dipping faults at either location, and it is possible that the observed faults relate to an earlier period of geological deformation. Alluvial fans have been deposited across the scarp. The fans have not been deformed by faulting and hence their deposition must post-date the last movement on the Bayan Hongor fault. Further investigation, potentially by palaeoseismological trenching, will provide further details of the sense of slip on the Bayan Hongor fault.

The western end of the Bayan Hongor system links with the left-lateral South Hangay fault (Fig. A2a). This close relationship indicates shortening across the Bayan Hongor fault, as the NW-SE trend constitutes a restraining bend absorbing the horizontal movement along the east-west strike-slip fault. This close relationship, when combined with our limited field observations, gives us confidence in stating that the Bayan Hongor fault is likely to be a thrust.

A2 Description of the Otgon fault

A fault trending NNW runs for more than 50 km from the main South Hangay strike-slip fault to the village of Otgon (Fig. A3a). The southern half of this fault was mapped as a normal fault by Cunningham (2001). It is clear from the digital topography and in the field that the fault possesses a large vertical component of slip (Fig. A3). Rivers draining southwest from the high interior of the Hangay have been interrupted by uplift of the western side of the fault. Drainage now ponds along the eastward-facing fault scarp in a series of internally drained basins (e.g. Fig. A3c). The original southwest directed channels are preserved as dry valleys and wind-gaps along the fault scarp (marked as white stars on Fig. A3a). Only the Buyant Gol has been able to retain its original course. Dip-slip is also apparent at a smaller scale, with young alluvial deposits showing clear vertical displacement across the fault trace (see Fig. A3b).

Some elements of the geomorphology suggest that the vertical component is a result of normal faulting. Triangular facets (a commonly observed feature of normal fault scarps) are present along much of the length of the fault (Fig. A4a,d). In addition, in some places where scarps are visible in young alluvium, the scarp consists of a step in height with a graben at its base (Fig. A4c). Geometries such as this, with fissuring present at the base of scarps, are usually indicative of normal faulting. However, neither of these observations are conclusive. The southern part of the Otgon fault occurs at a restraining bend in the main trace of the east-west left-lateral South Hangay fault. The fault presumably accommodates shortening within this restraining bend and, as such, is likely to have a reverse component of slip.

The linear fault trace is indicative of a steeply dipping fault. South of 47E, the fault splits into two strands (Fig. A4a and e). The western strand cuts straight across a hillside with deeply entrenched drainage channels. The fault trace is not deflected as it crosses these undulations in the topography suggesting that the dip is close to vertical. The apparent vertical dip is indicative of strike-slip, as dip-slip faults are typically not steeper than ~60°. Several steep gullies run down the scarp. The western scarp cuts through the gullies and appears to displace two of them right-laterally (Fig. A4f). Where visible in young alluvium, the trace of the fault is also somewhat suggestive of strike-slip, with a trace that appears to consist of short en-echelon segments. However, the geomorphology is not well enough preserved to assess this geometry fully.

Our field investigation was too brief to provide definite information on the slip direction of the Otgon fault. The presence of a vertical component of slip is obvious, but we have been unable to confirm whether this component results from normal or reverse faulting. We have also presented some indications of strike-slip faulting potentially of right-lateral sense, but none of our observations are particularly convincing on their own. Whatever the details of the slip direction

on the Otgon fault, it is closely associated with the South Hangay strike-slip fault, and is therefore likely to be accommodating the same strain. The orientation and suggested oblique right-lateral sense of slip on the Otgon fault are somewhat similar to the Teregtiyn (reverse and right-lateral) and Dungen (right-lateral) ruptures branching from the main east-west left-lateral surface breaks of the 1905 Bulnay earthquake (e.g. Balyinnjam et.al. 1993). Presumably the Otgon fault is related to the South Hangay fault in a similar way that the Dungen and Teregtiyn segments are related to the Bulnay fault. Further field investigation will provide details on the structure.

A3 References

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Cunningham, W.D., 2001, Cenozoic normal faulting and regional doming in the southern Hangay region, Central Mongolia: implications for the origin of the Baikal rift province: Tectonophysics, v. 331, p. 389-411.

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Supplemental figures

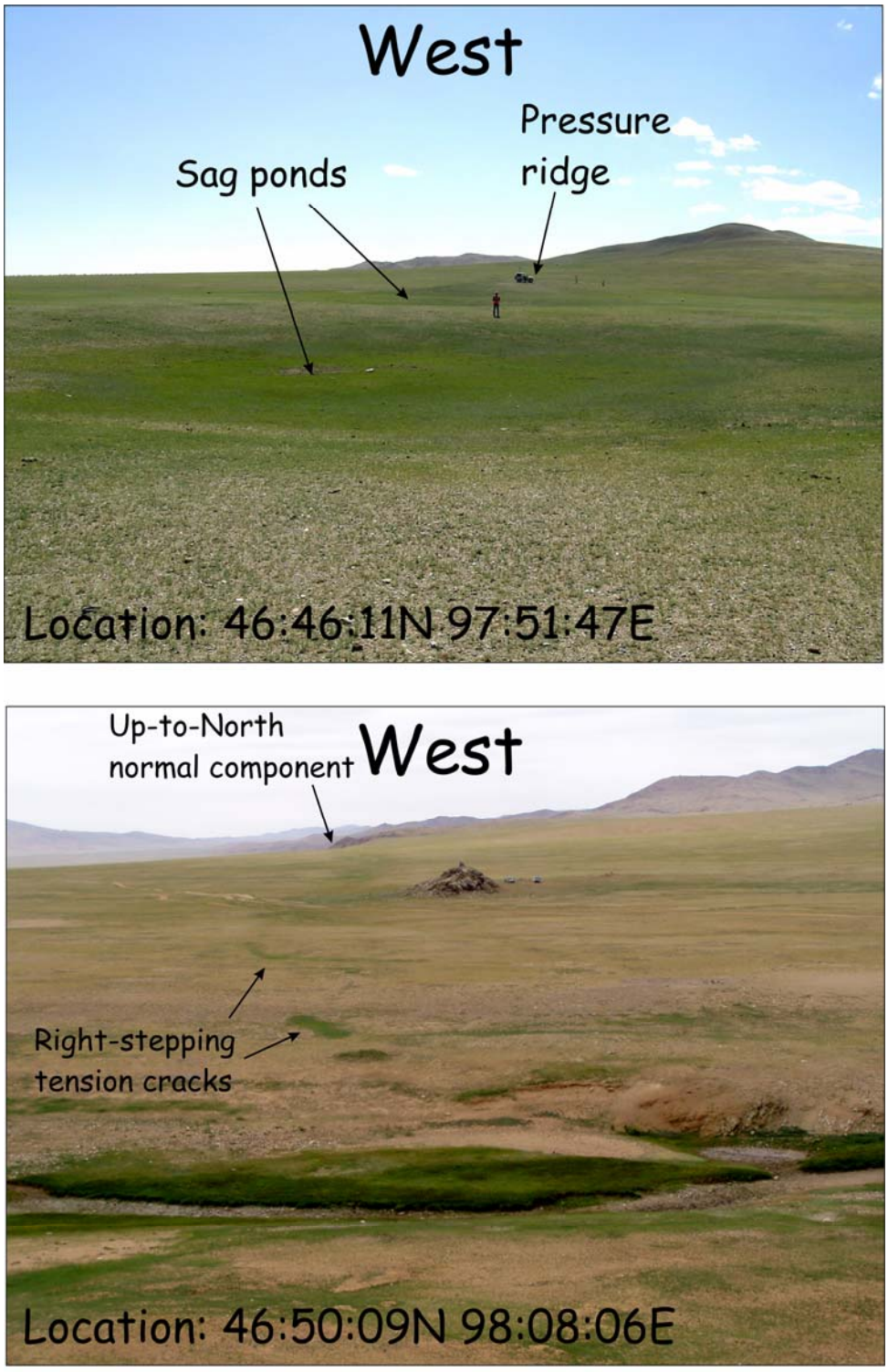

Figure A1: Enlarged versions of the field photographs presented in Figures 2b and 2d of the main text.

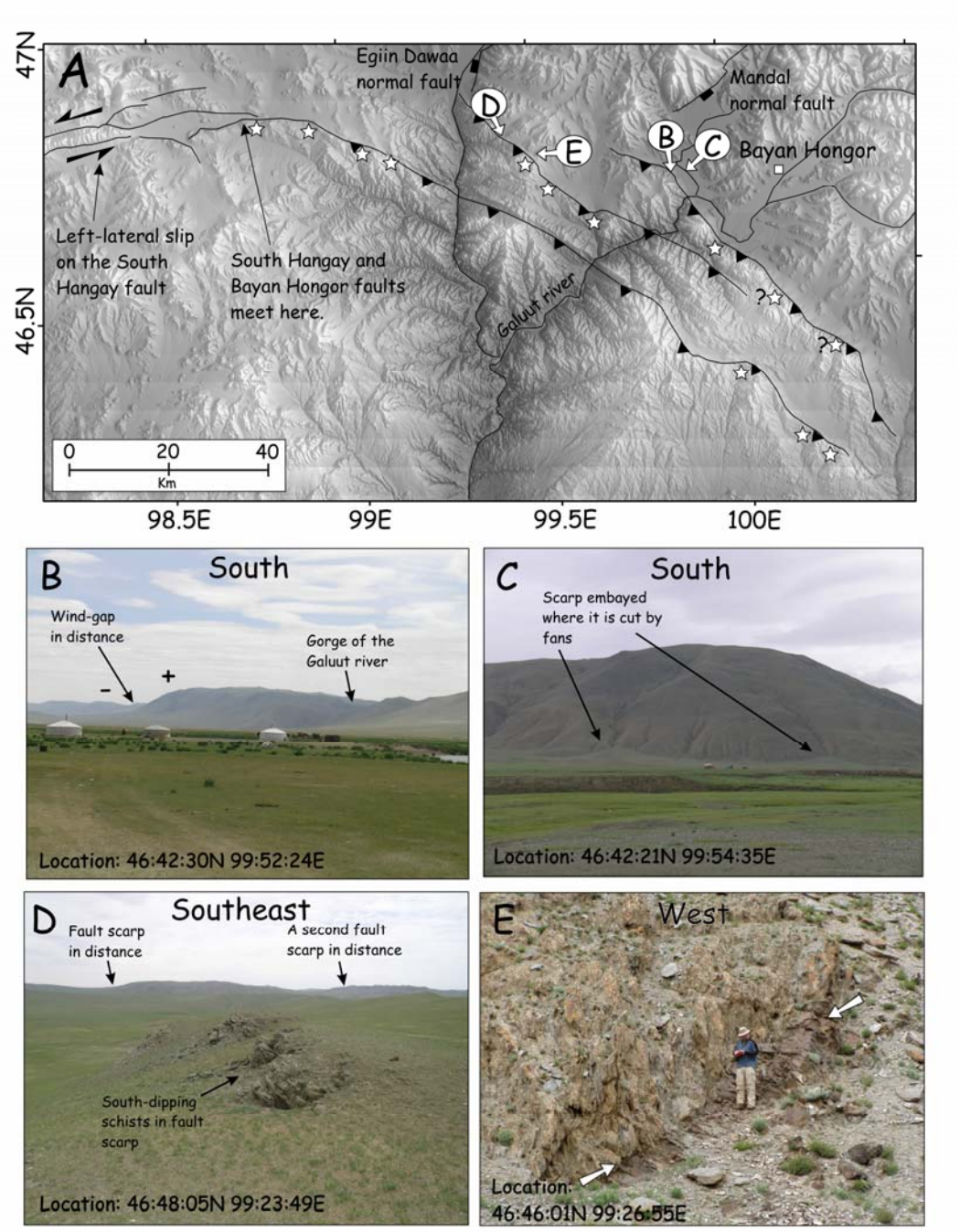

Figure A2

Figure A2: (a) Colour image of the shaded relief SRTM topography (Farr and Kobrick, 2000). Locations of field photographs are marked. (b) View south along the scarp of the Bayan Hongor fault. Two topographic lows along the ridge represent the active channel of the Galuut river (foreground) and an abandoned channel (in far distance). (c) View southwest at the Bayan Hongor scarp. Alluvial fans crossing the scarp are not deformed by faulting. Hence the fault trace is embayed at the fans. (d) View southeast along the Bayan Hongor scarp. South-dipping schists are exposed along most of the fault length. Another parallel fault scarp is visible in the distance to the south. (e) View of a south-dipping fault exposed in the Bayan Hongor scarp (this image was presented as black and white in figure 3b).

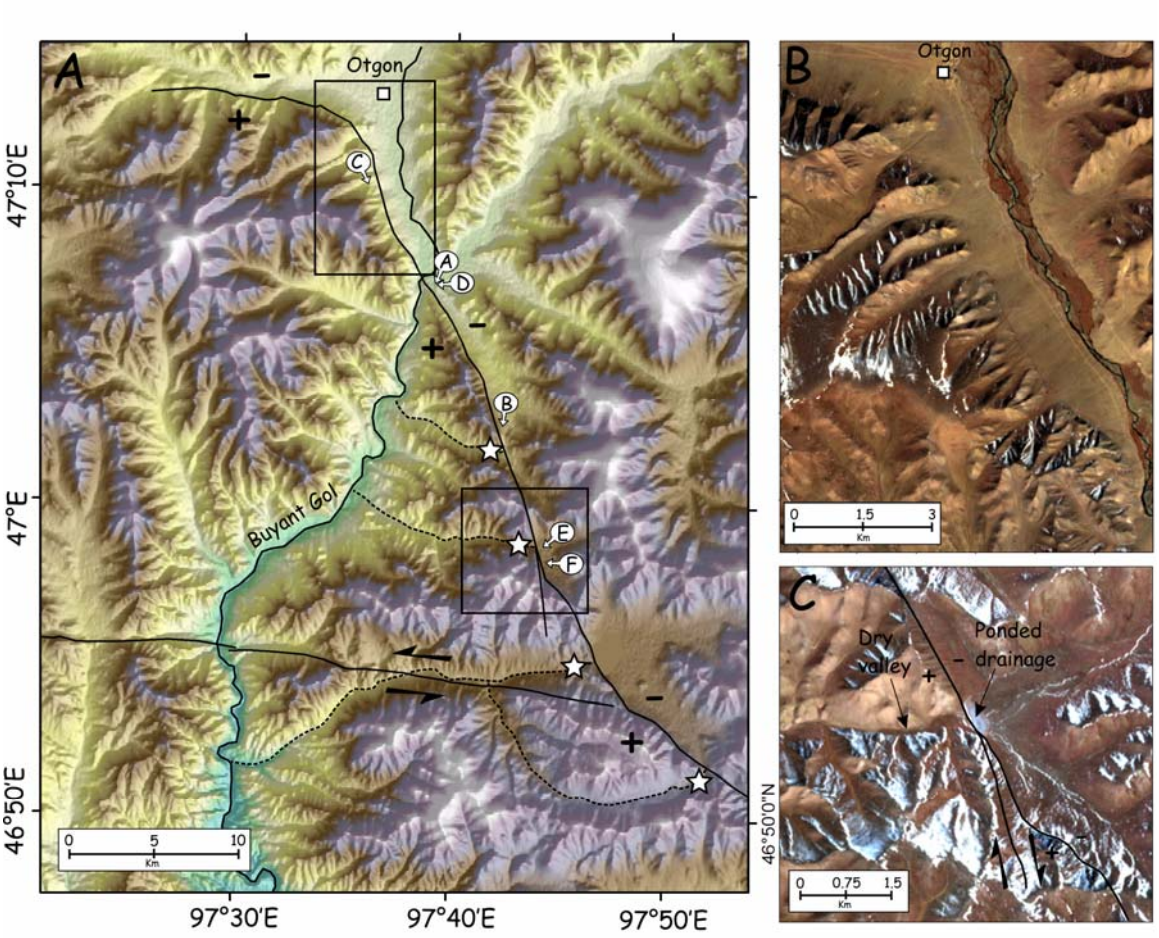

Figure A3

Figure A3: (a) Colour image of the shaded relief SRTM topography. Locations of field photographs in figure A4 are marked. (b) ASTER satellite imagery (acquisition date 2004:10:13, RGB bands 3n,2,1) of the northern section of the Otgon fault. The fault is picked out as a line of vegetation (red in this image). (c) ASTER satellite image of a southern part of the fault. An abandoned drainage channel is visible in the western, uplifted, side of the fault. Drainage has ponded at the scarp in a small lake. South of the small lake, the fault splits into two strands. The western of these two strands has a remarkably linear trace across undulating topography, suggesting a very steep fault with a component of strike-slip.

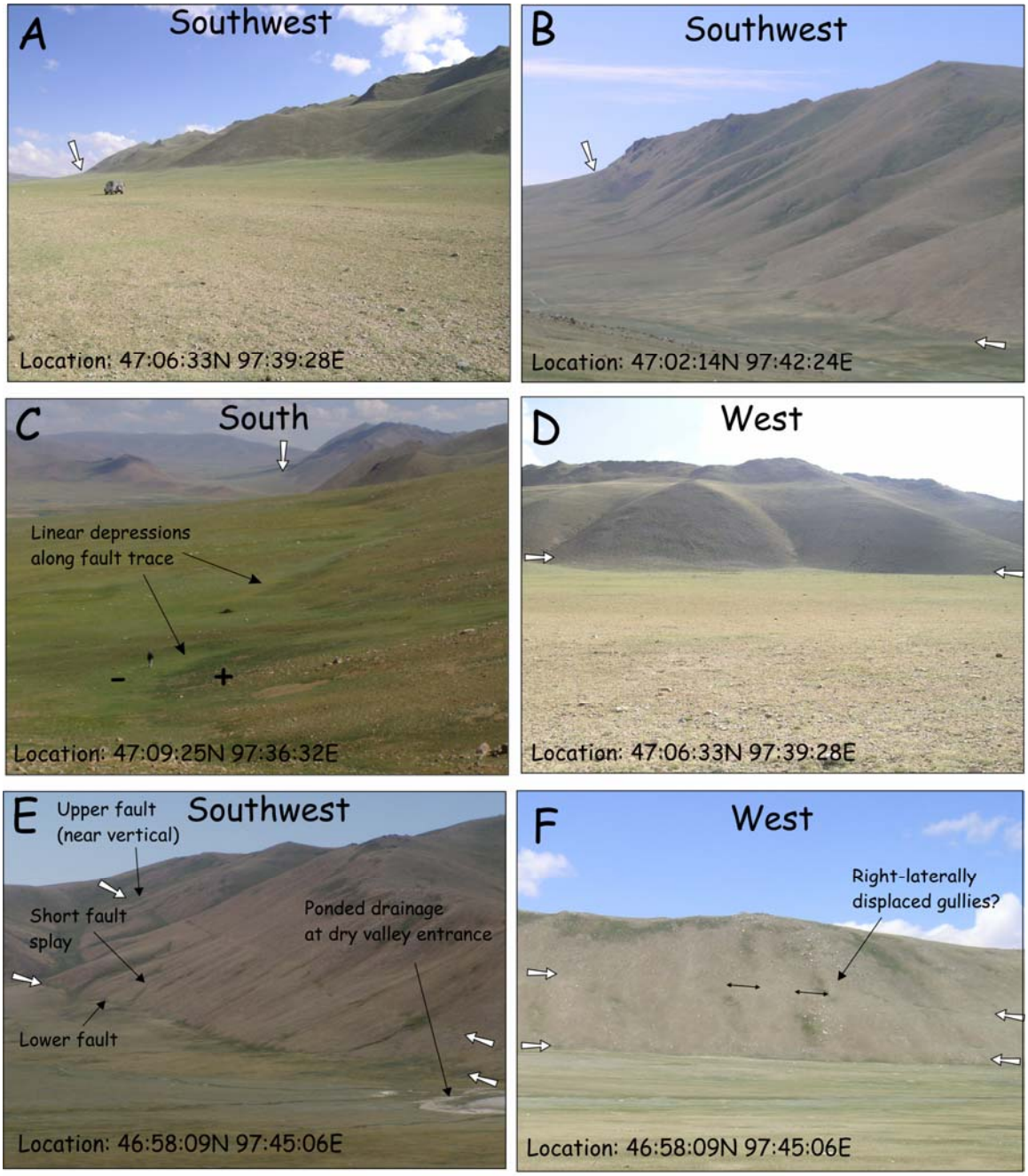

Figure A4

Figure A4: Field photographs of the Otgon fault. (a) View southwest along the fault showing east-facing scarp. Fault at horizon marked by a white arrow. (b) Similar view showing steep east-facing scarp. (c) View south at fault trace in alluvium. A height change (up to the west) is visible across the trace. A series of grassy depressions run along the base of the scarp potentially indicating a normal sense of slip. A figure shows the scale. (d) Looking west at well-developed triangular facets on the fault scarp. (e) View southwest at two splays of the Otgon fault. The more westerly splay tracks uphill across rapidly undulating topography. In map view its trace is linear (see Fig. A3) suggesting a very steep dip. (f) View west at the two fault splays shown in (e). The upper fault appears to displace gullies in a right-lateral sense though this observation is not certain.