KILIMANJARO SAFETY PATROL RECONNAISSANCE EXPEDITION
25th - 27th January 2006

An investigation to determine the cause of the Western Breach accident of 4th January 2006 and to offer recommendations for the way forward for this route.

1. Description of Western Breach

fig 1

Location of Arrow Glacier Camp: 03°04.580' S, 037°20.357' E. Altitude: 4871m
Location of point of entry onto Crater: 03°04.396' S, 037°21.105' E. Altitude: 5726m
Mean gradient of slope: 38.0°
Mean gradient of route: 26.0°
Linear distance from Arrow to Crater: 1.39km
Route distance from Arrow to Crater: 1.95km

The present route ascending the Western Breach can be said to consist of 7 phases:

1) Route zigzags on scree slope from Arrow Camp at 4871m,
2) attains red rock band at 5090m,
3) emerges from top of red rock band at 5205m where attains scree slope 230 metres beneath right arms of r-shaped glacier,
4) trail moves diagonally left on scree before switching right to cross tributary (2nd water point, sometimes frozen) at 5308m at halfway point en route to crater lip,
5) trail continues diagonally right to top of 'rock train' where attains rock spur until base of crater wall
6) ascends rock tower with series of switchbacks and rock steps before emerging onto narrow scree slope,
7) route moves diagonally right across scree band to emerge through crater wall onto crater at 5726m.

'O' indicates location of Western Breach on Kibo's south west face

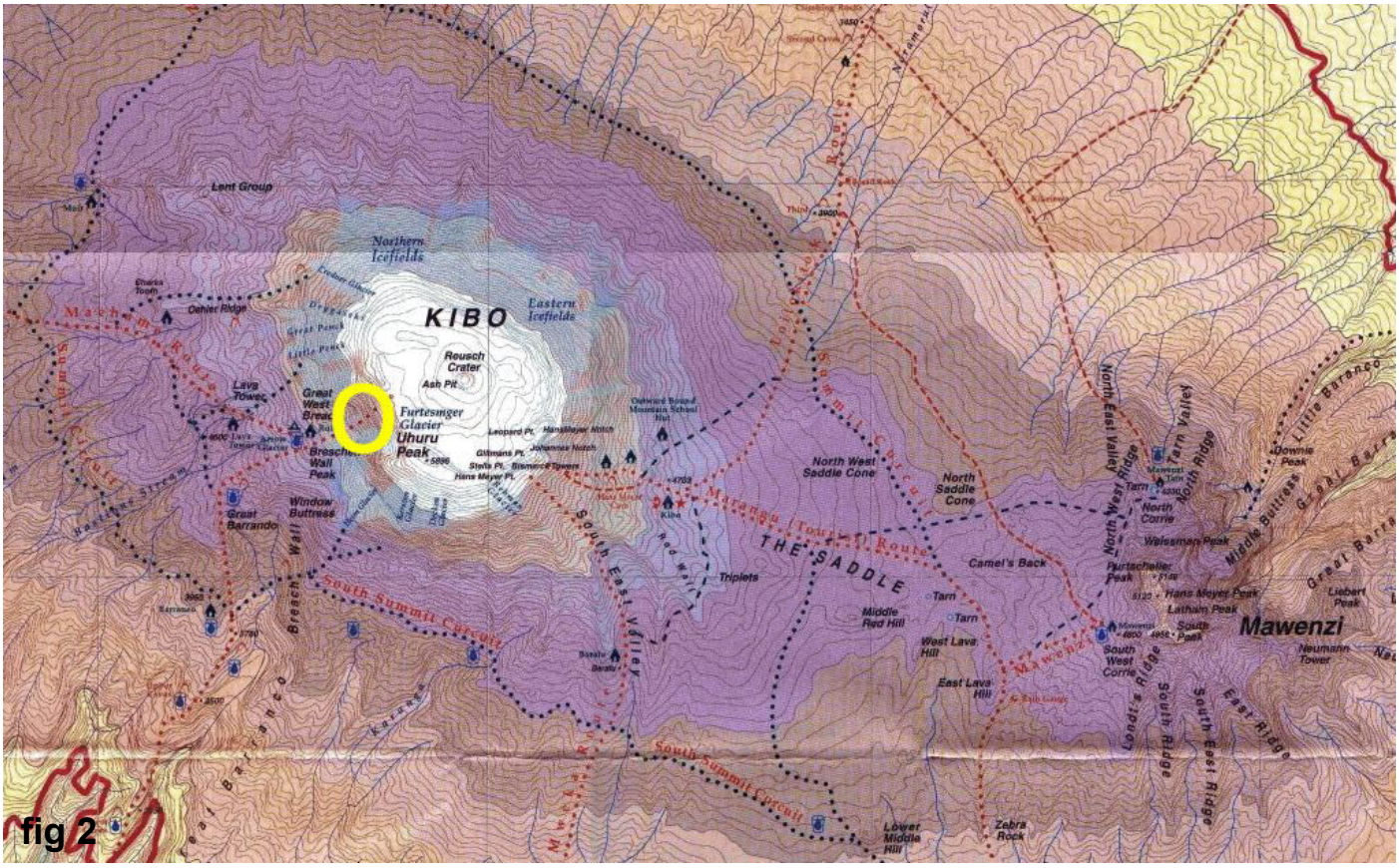

fig 2

2. Causes of the Accident

Residual glacial deposit assumed to have been formed over many years at intersection between left and right arms of r-shaped glacier (see figure 5). Part of this deposit collapsed, estimated by group at 39 tonnes[1], sliding 150 metres down the slope, reaching a group estimated speed of 39 metres per second[2] at the point where the climbers were struck.

Cause of dislodgement: melting of ice in ice-scree composite bonding residual glacial deposit combined with strong downhill winds measured at 177 km/h on morning of accident[3]. Climbers failed to respond to threat because of following factors:

- estimated only 4-5 seconds* before sound emanating from rocks gathering speed reached climbers;
- strong winds deflecting sound;
- poor visibility with snowfall.

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[1] the team examined a conspicuous cavity at the accident source site from where the recent fallen rocks were believed to have been dislodged that caused this accident. Based on the apparent concentration of remaining rocks adjoining this area, members estimated the number of 7 tonne truck loads required to re-fill this cavity. An average was taken and the figure of 39 tonnes arrived at.

[2] based on compared experiences of three members of the team who themselves had been exposed to rockfall. see Appendix B.

[3] measured by Zara Guide George Lyimo during ascent of Western Breach Route on morning of accident, using Austrian manufactured "Ciclo" wind speed gauge wrist unit, assumed error of 5%. Lyimo quit camp approximately 3 hours before the deceased. *mean velocity = distance / time, thus (39 - 0)/2 = 150 / t, thus t = 7.7 seconds. Subtract from this time taken for sound to reach climbers, 0.5 seconds, (speed of sound = 300 m/s), thus time between sound and rock reaching climbers = 7.7 - 0.5 = 7.2 seconds. It is assumed that while rock begins to become dislodged a significant volume of sound is not emitted within the first 2-3 seconds, before the originating rocks begin to impact other rocks and build speed.

Figure 3 (below) shows view from r-shaped glacier over residual glacial deposit towards point where climbers were struck. The distance from point A to point B is estimated at 150 metres.

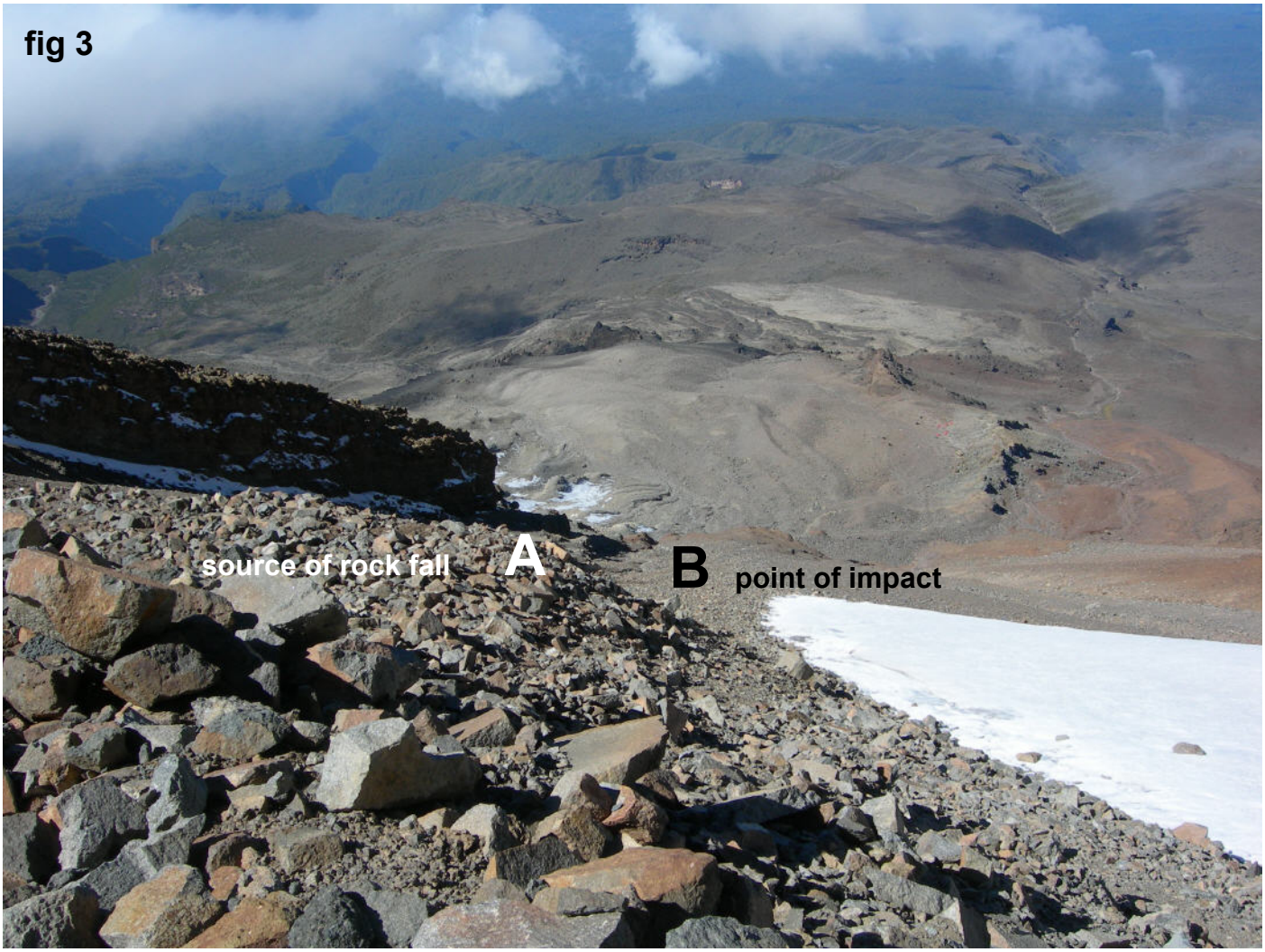
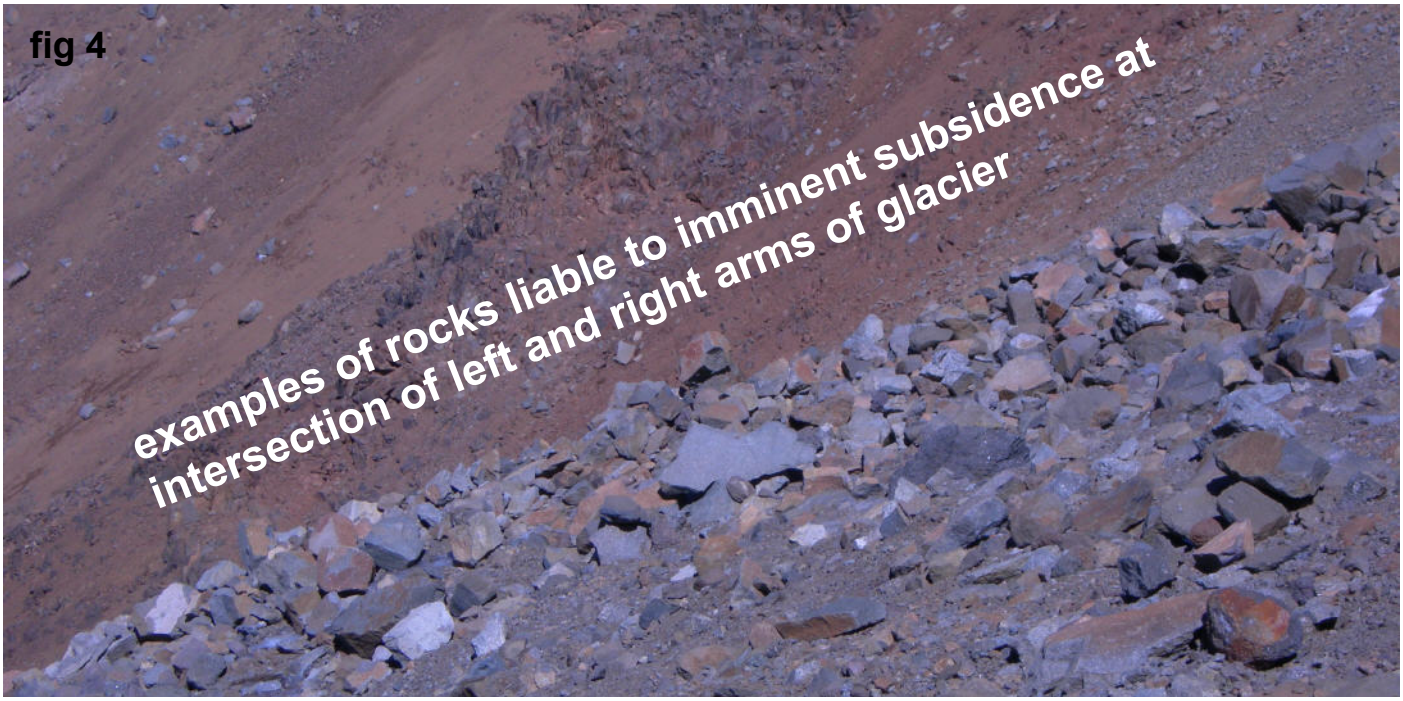


Figure 4 (below) shows area near to source of rock fall of 4th January and is believed to be liable to imminent subsidence.



3. Current Status of Route

The route is judged currently to be not safe with special concern over two risk zones:

Risk Zone A (yellow, below): residual glacial deposit at intersection of right and left arms of r-shaped glacier resulting in a death risk from rock fall zone from 5180m to 5315m.

Risk Zone B (red, below): crater wall and rock tower subsidence at 5440m to 5780m resulting in a death risk from rock fall zone from 5280m to 5480m.

The remainder of the route is judged to be subject to no specific identifiable imminent threats.

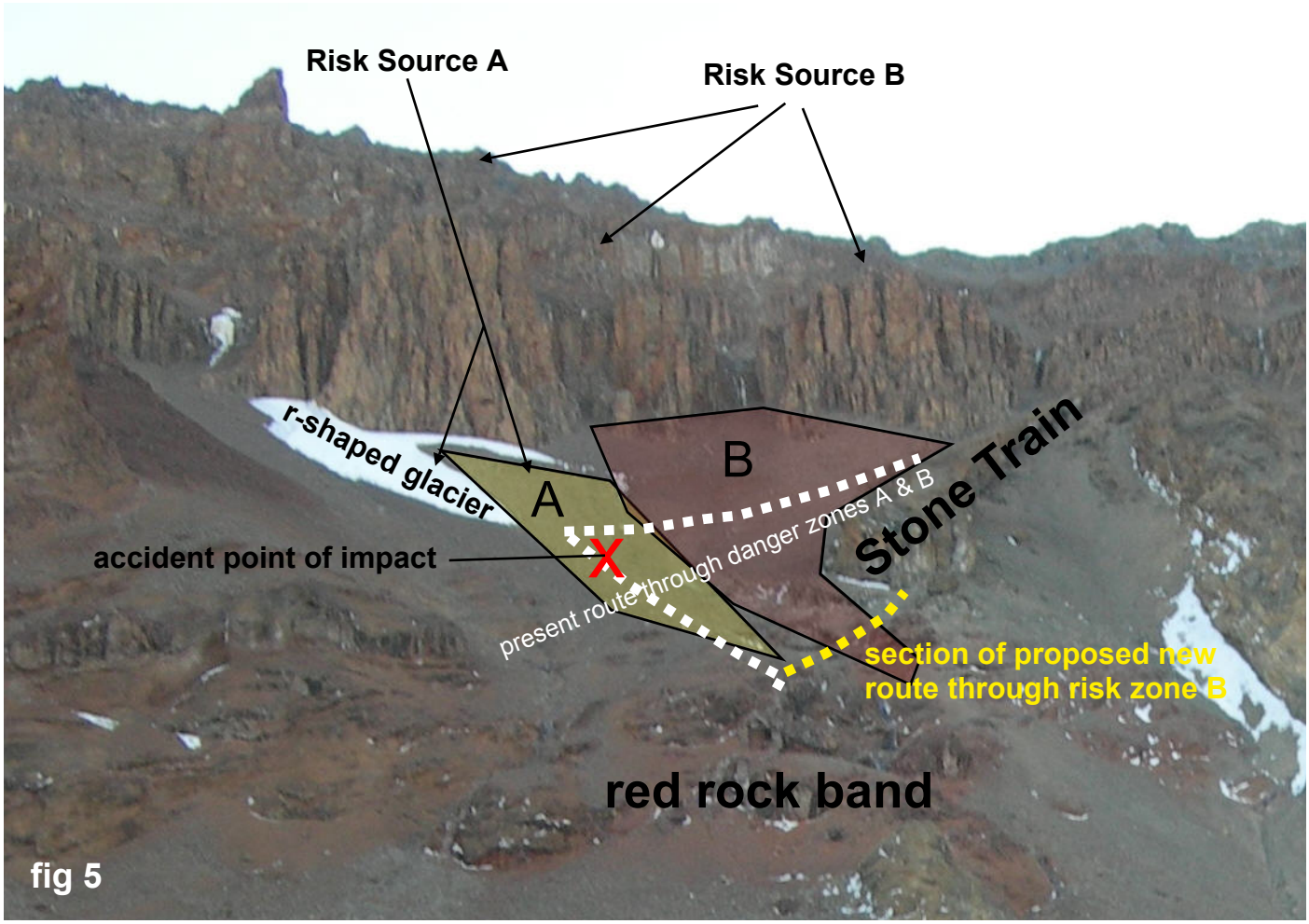


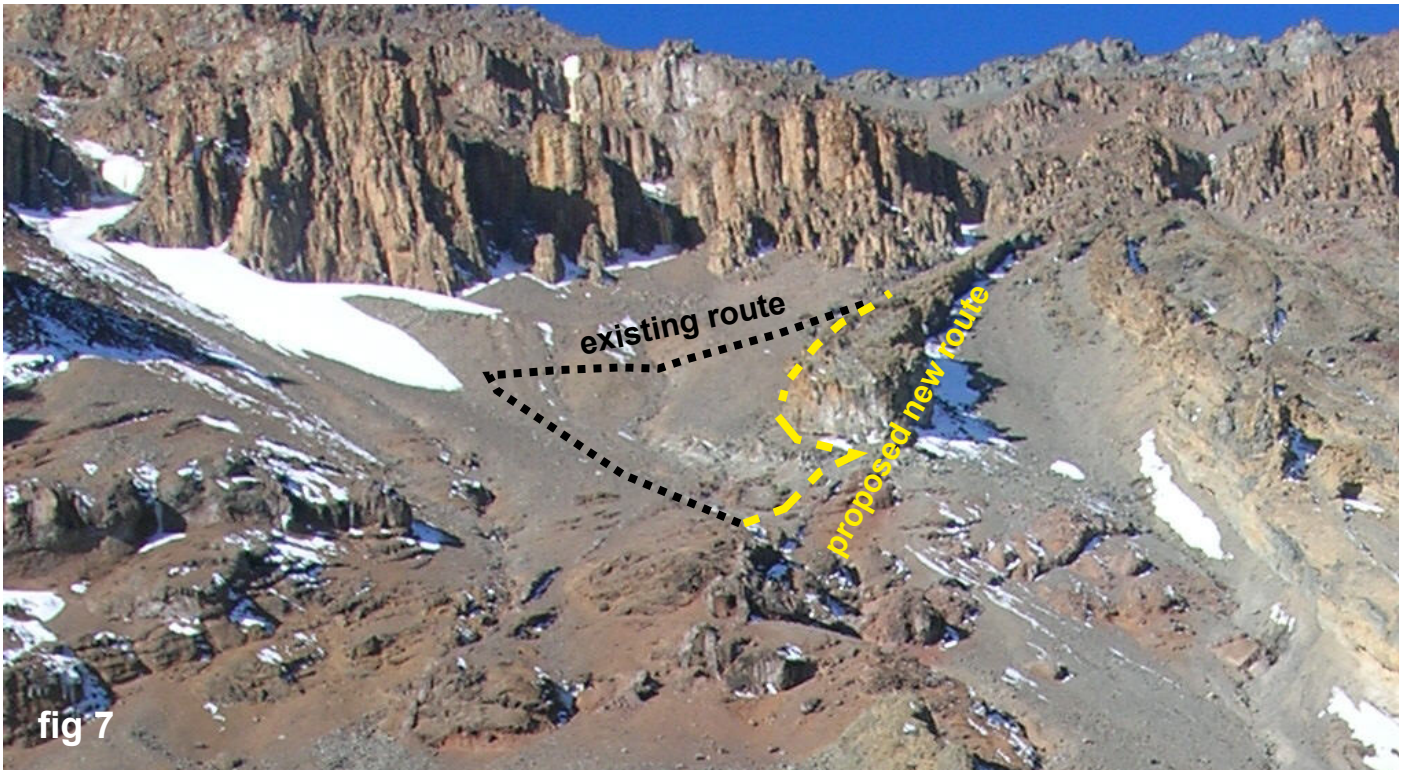
fig 5

fig 6

mounting rock deposit at intersection of left and right arms of r-shaped glacier representing ongoing risk source associated with Risk Zone A

4. Recommendations

1) Our principal recommendation is to divert the route from near the top of the red rock band to the base of the prominent rock feature known as the 'Stone Train'. The route should proceed to handrail up the left hand edge of the Stone Train to attain the rock spur adjoining the base of the crater wall at approximately 5400m.



2) A signboard should be erected at Arrow Glacier camp stating the following, or similar:

"The Western Breach ascent route is subject to considerable objective risk, primarily from rock fall. Climbers should be aware that while it is not possible to avoid all risk, in order to minimize exposure to rock fall, ascents should depart from Arrow Glacier camp no later than 5:30 am."

3) The route should be clearly signposted with prohibitions not to proceed beyond the red rock band. The new diversion should be clearly marked with warning sign advising climbers that they are entering a rock fall risk zone and requesting that they proceed swiftly across the demarcated zone to the base of the Stone Train. The Stone Train diversion route should be well prepared with steps cut to assist swift passage across tributary at base of risk zone B. The team believes that this measure will reduce the time spent in a rock fall risk zone from some 55 minutes to 5 minutes.

4) Consultation with, and commissioning of studies by, further specialists (seismologists, glaciologists, geologists, meteorologists, etc) to assess the long term future risks associated with climate change and Kilimanjaro's altering geology and glaciology.

5) The present team to form the basis of a future safety patrol team tasked with visiting the mountain on a monthly or bi-monthly basis to survey and identify possible future risk areas in the light of the rapidly changing climatic situation on Kilimanjaro. The team believes the following areas to merit close and regular inspection:

1) Western Breach
2) Barranco Breach Wall
3) Area beneath the Kersten and Decken Glaciers
4) South East Valley beneath Stella Point
5) Final re-entrant before attaining Barafu Rib on the Machame Route
6) Area between Hans Meyer Cave and Gilman's Point
(On 29th January the team learned that precisely this area had suffered rock fall only 3 days prior).
7) Lava Tower

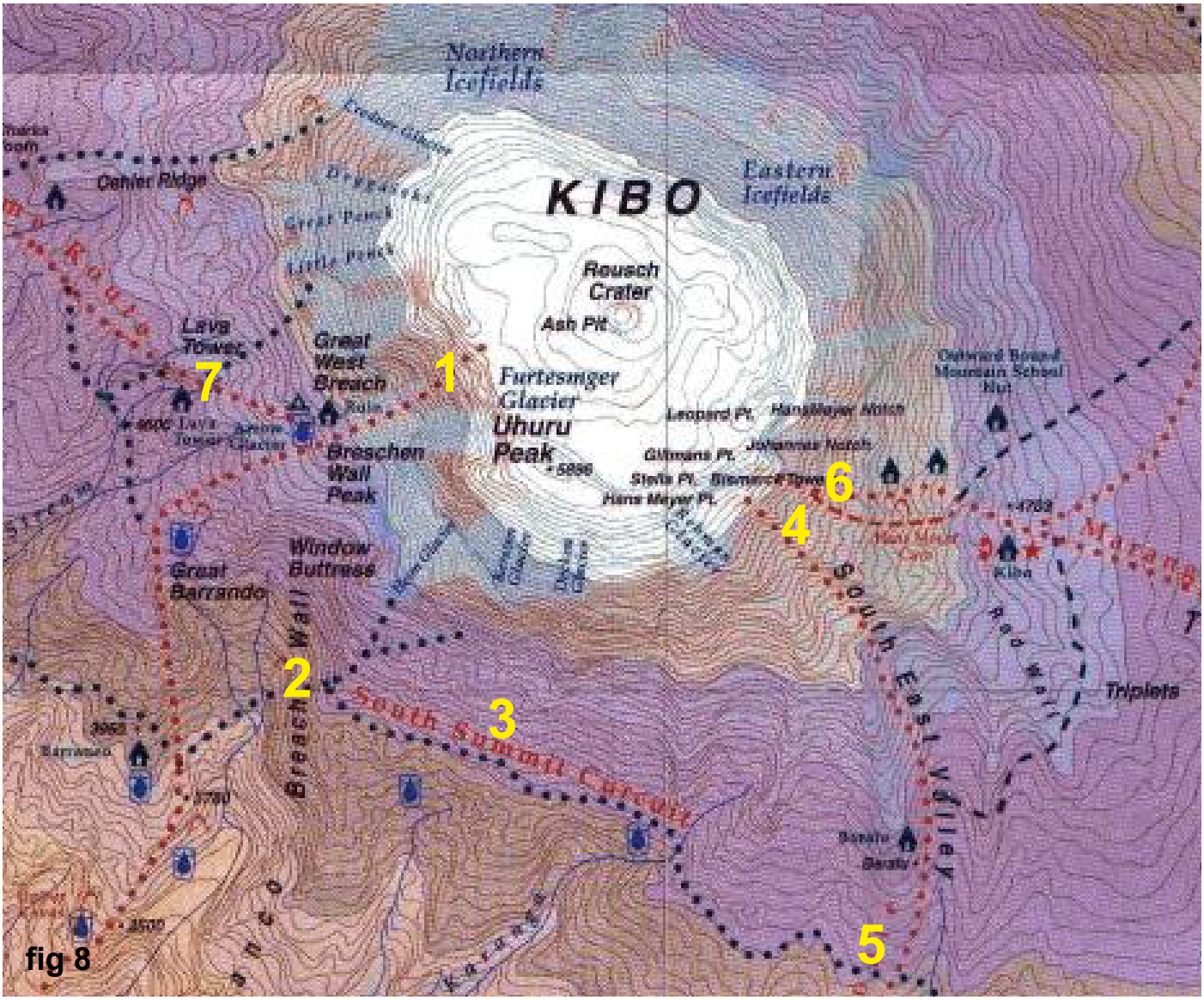


fig 8

It would be hoped that this team would be instrumental in averting future disasters by offering appropriate recommendations to contain or evade perceived threats throughout Mount Kilimanjaro.

7) A survey of visitors to Kilimanjaro National Park should be conducted in order to ascertain the general feeling of the tourist community towards the prospects of:

a) closure of the Western Breach ascent route
b) continuing to conduct ascents via the Western Breach despite proven risks of ongoing possible rock fall, albeit following the implementation of a new route section that will significantly reduce exposure to these hazards
c) continuing the use of the other two assault routes on the mountain, via Barafu and Kibo Huts, which are also believed to be becoming more risk prone as rock bonding agents throughout the mountain lose integrity with perceived rising temperatures and a reduction in precipitation generally.

Appendix A

Mathematically, the maximum speed obtainable by a rock falling in ***unresisted freefall*** from the source site (130 *vertical* metres above point of impact) would be 113 mph by the time it reached the casualties:

1): (V2 - V1) / t = a = 9.81 m/s/s, thus, 9.81t = V2 - V1
2): (V2 - V1) / 2 = d / t, thus, (V2 - V1) / 2 = 130 / t, thus, 260 = t(V2 - V1), and V2 - V1 = 9.81t, thus, 260 = t(9.81t), thus,

$9.81t^2 = 260$, thus, $t = \sqrt{(260 / 9.81)}$ Thus, t = 5.15 seconds, thus max. mean velocity = 130 / 5.15 = 25.24 m/s, thus max final velocity (in ***freefall***) = 2 x 25.24 = 50.5 m/s = 182 km/h = **113 mph.**

The Team:

Imani Kikoti	Park Warden, KINAPA	Acting as Chairman
Joseph Paul Nchereri	Athlete, Team Kilimanjaro	Acting as Secretary
Ambrose Mlay	Rescue Ranger, KINAPA	Member
George Lyimo	Guide, Zara Tours	Member
Elias Msemo	Guide, African Environment	Member
John Rees-Evans	Director, Team Kilimanjaro	Member

Signed:

Imani Kikoti 6/2/06

Imani Kikoti, Chairman

Joseph Paul Nchereri, Secretary

Left to right: Ambrose Mlay, Elias Msemo, George Lyimo, John Rees-Evans, Imani Kikoti.
Photo: Joseph Paul Nchereri

Appendix B

The estimate of 39 metres per second (140.4 km/h or 87.2 mph) is based on the compared experiences of three team members (Elias Msemo, George Lyimo and John Rees-Evans) who themselves had been exposed to rock fall on previous occasions and who for the purpose of this report each independently estimated the speed at which rock fall that they had witnessed had passed them on similarly angled slopes to that beneath the r-shaped glacier from the base of which the recent rock fall was dislodged. An average of these three estimates was taken. This method is *not* claimed to be systematic or accurate however we believe it to be a reliable approximation. The team is aware that an eyewitness survivor estimated the falling rock to be travelling at "150 mph" but as this rock originated only 150m above the accident site the accelerative force acting on this rock would be required to be in excess of the resultant gravitational force acting upon an unresisted rock in freefall:

150 mph = 67.1 m/s

time required for unresisted projectile in *freefall* to obtain this speed = $\frac{\textbf{67.1 (m/s, final velocity)}}{\textbf{9.81 (m/s/s, gravitational acceleration)}}$ = 6.8 seconds

With the accident being sited at a max. elevation of 5280m (evidence was recovered from 5245m) the rock fall would have been required to have originated at 5736m which is above the level of the crater wall at this point:

final velocity = $\frac{\text{distance}}{\text{time}}$ thus, 67.1 = $\frac{x}{6.8}$ therefore x = 456.3 metres, added to 5280 = 5736 metres elevation

Further, note that these calculations describe a rock in freefall which we would judge to be considerably faster than that of a rock rolling down a 30 - 40 degree slope.