SINET: Ethiop. J. Sci., 22(1):127–140, 1999
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Short communication

LANDSLIDE HAZARD ON THE SLOPES OF DABICHO RIDGE, WONDO GENET AREA: THE CASE OF JUNE 18, 1996 EVENT

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ABSTRACT: The eastern escarpment of the Awassa basin, rising to 2400 m.a.s.l. is characterised by steep slopes resulting from faulting and volcano tectonic collapse of the Awassa caldera. Landslide scars are prominent on this escarpment showing the potential danger of mass wasting. Here we present the nature and distribution of land slides which occurred in this area, along the Dabicho ridge on June 18 following the June 17, 1996 heavy rainfall (61 mm). At one site a family of eight persons died due to the hazard. The necessity of undertaking extensive geological and geomorphological studies in order to prevent future disasters is discussed.

Key words/phrases: Dabicho ridge, hazard, landslide, rainfall, Wondo Genet

INTRODUCTION

The highlands of Ethiopia are largely affected by slope instability and landslides because of the presence of high and steep slopes (made by tectonic-volcanic activity or fluvio-denudational processes) and the recurrent occurrence

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of triggering factors such as high rainfall, mostly concentrated in the rainy season (Griffiths, 1962; Daniel Gamachu, 1977) and high magnitude earthquakes (Gouin, 1979).

Depending on the nature of the bedrock lithology and slope morphology, different types of landslides may be produced:

i) On steep slopes characterised by hard bedrock, such as basalt, welded ignimbrite, limestone and sandstone, rapid phenomena (including rock falls, topplings, rock slides and avalanches, debris and mud flow) are common. On high relief escarpments these phenomena may involve huge masses of rock, up to several cubic meters in volume. They are often triggered by earthquakes even though some of them may occur after a long preparatory phase, without any apparent cause.

ii) On steep slopes of deeply weathered volcanic rocks, rapid landslides mostly involving the eluvial-colluvial cover (debris slides and avalanches, debris and mud flow) are particularly frequent. The main triggering factor for these phenomena is heavy rainfall.

iii) On clayey materials such as lacustrine deposits or clayey sedimentary formations, slower landslides, such as rotational or translational slides, sometimes passing to earth flow or mud flow (Varnes, 1978; Cruden and Varnes, 1993) may be observed. The biggest ones have step like evolution alternating long periods of quiescence with very short phases of reactivation, triggered by extreme rainfall events or earthquake shocks.

The above mentioned phenomena may be extremely dangerous for people, settlements and infrastructures. Nevertheless, only few studies have been made so far on these relevant topics (Lulseged Ayalew and Berhanu Temesgen, 1995; Ogbaghebriel Berakhi, 1995; Almaz Gezahegn, 1996; Asfawossen Asrat *et al.*, 1996; Ogbaghebriel Berakhi *et al.* (1993a,b).

This paper presents a case study of landslides which occurred on June 18, 1996, on the slopes of the eastern margin of the Awassa basin (Southern Ethiopian Rift Valley), an area characterised by high hazard conditions according to Raunet (1974). The area is known to have been affected in the past by a large number of landslides, as testified by geomorphological evidences (*e.g.*, fresh unvegetated scars on the slopes, concave-convex profiles, large amount of debris and blocks at the footslopes), archive data (Gouin, 1979) and reports by residents. The method used to undertake the present study include geological, geomorphological and tectonic studies in the field, size and slope measurements of landslide surfaces, topographic map and aerial photo interpretations and analysis of rainfall data. Seismic data collected by the geophysical observatory has also been considered to test the hypothesis for the possible causes of the landslides.

GEOLOGICAL - GEOMORPHOLOGICAL AND TECTONIC SETTING OF THE STUDY AREA

The Awassa basin is a depression - a large caldera (25 to 30 km in diameter) - which was generated by volcano-tectonic collapse phenomena. It is bounded on all sides by high and steep fault escarpments (Mohr, 1962; 1967; Di Paola, 1972; Gèze, 1974; Raunet, 1974). The most prominent of these is the eastern cliff where, due to the volcano-tectonic collapse, an elevation difference of approximately 1000 m between the rift floor and the eastern plateau has been produced.

Regional studies (*e.g.*, Di Paola, 1972; Raunet, 1974) indicate that the Wondo Genet area is marked by Tertiary and Quaternary geological formations. The Wondo Genet area consists mainly of acidic rocks (alternating layers of ignimbrites, pumaceous tuffs and volcano lacustrine deposits) interbedded with basaltic lava of probably Tertiary origin (Fig. 1). The area under consideration lies on the eastern fault escarpment, specifically on the slopes of the Dabicho Ridge (Fig. 2). The outcropping bedrock consists of alternating layers of pyroclastic materials (ignimbrite, tuff, agglomerates) and basalt, mostly dipping down slope and cut by a dense network of joints and faults. Due to the presence of bedrock layers with differential resistance to weathering and erosion, the slope shows a stepped profile of alternating structural scarps and terraces.

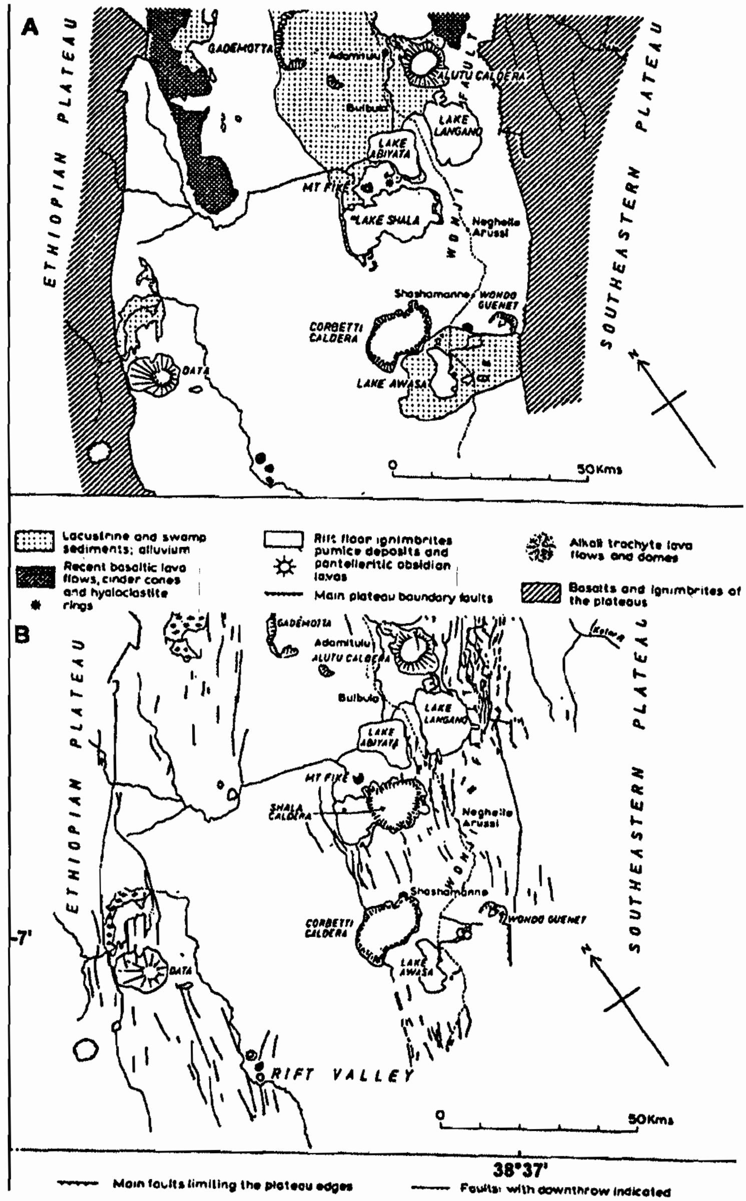

Fig. 1. Geological and Tectonic Map of the Awassa - Wondo Genet Region (simplified after Di Paola, 1972).

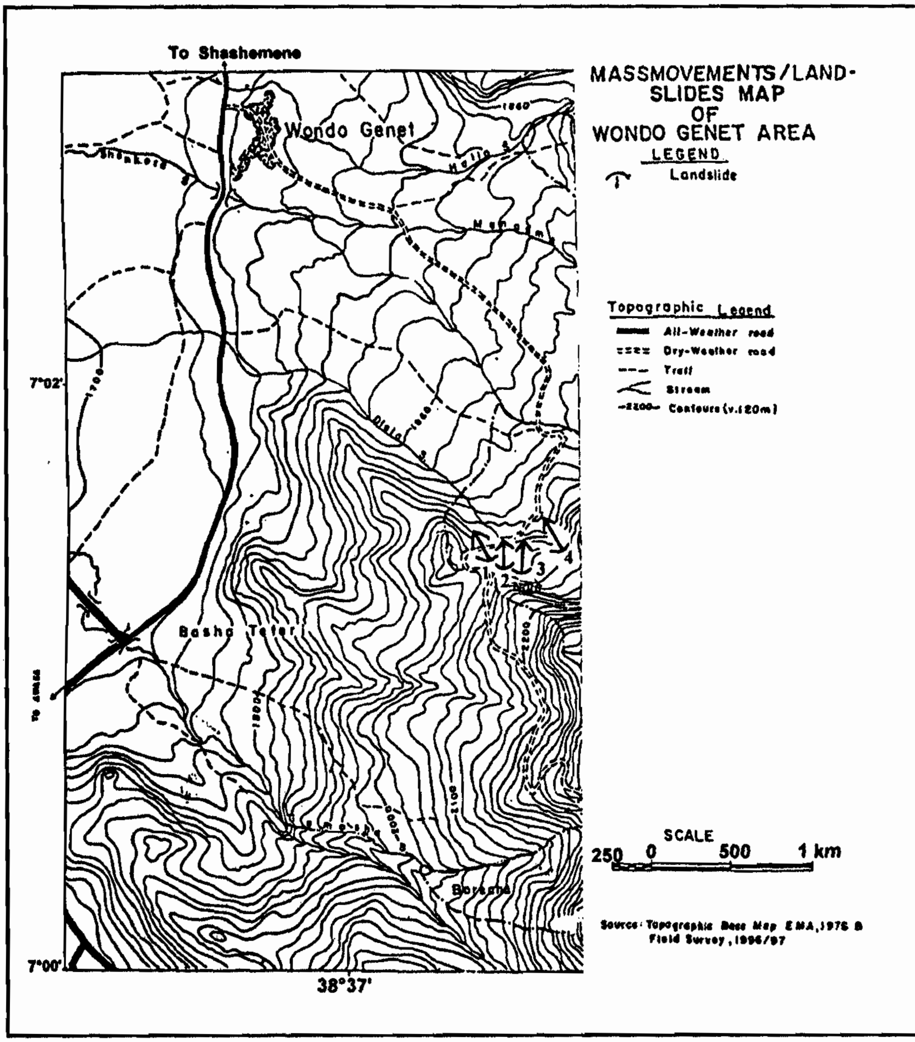

Fig. 2. Location map of the study area (indicating the four landslide sites: 1, 2, 3 and 4).

The foot slopes, between the escarpment and the lower Awassa plain, are made of thick depositional fringe of variable width (300 to 3000 m), consisting of alluvial-colluvial fans, landslide scree terraces, blocks of ignimbrites and basalts measuring several meters in size.

Present day pedogenesis has developed brown soils which are superimposed on ferralithic red soils, produced in the past probably under wetter climatic conditions (Raunet, 1974).

CLIMATE, VEGETATION, SOIL AND LAND USE

The eastern escarpment, with an annual precipitation of about 1200 mm, is the wettest part of the Awassa basin. Most of the rainfall is concentrated during spring (February and March) and summer months (June to September) when very heavy rainfall events may occur. Due to the presence of alternating lithologies with different permeability, many springs are present in the area. Some of them (*e.g.*, Wondo Genet spring) are fed by thermal water (Tesfaye Chernet, 1982).

Natural vegetation in the area is of humid-tropical type (Chaffey, 1975; Ethiopian Mapping Authority, 1988) with *Acacia abyssinica, Albizia gummifera, Cordia abyssinica, Podocarpus falcatus, Croton macrostachys* among others.

Notwithstanding the widespread deforestation which has affected the area until very recent times (Raunet, 1974), wide remnants of the original forest still remain on the slopes and, to a lesser extent, on the flat plain of the basin where intensive cultivation is practised. Due to increased human settlement steep slopes are being heavily cultivated, and the natural forests are gradually disappearing. Chat, coffee, banana, enset, sugar cane, avocados, maize, *etc.* are intensively cultivated in the area. A network of irrigation ditches, fed by spring waters is also present across and occasionally along the slopes.

The Dabicho landslides

Landslides occurred at four different places on June 18, 1996 on the slopes of the Dabicho Ridge in the Wondo Genet area, at an altitude of about 2000 m.a.s.l. (Fig. 2). The area is characterised by steep slopes and step-like landscape. Such step - like landscape, as has been observed in similar tectonic and geological settings (Asfawossen Asrat *et al.*, 1996) may indicate that the area might have been affected by earlier landslides creating steep slopes where materials had been removed from and gentler topography in places of deposition. The overburden, which consists of soil and debris, overlying the volcanic bedrock, may form an irregular slope.

According to reports by local people the landslides occurred in coincidence with the heavy rain which fell continuously for several days and flooded the Wondo Genet plains and Awassa area. Of particular significance was the torrential rain (61 mm) (Fig. 5) that fell uninterruptedly for 17 hours, from June 17, 5 p.m. to 10 a.m. the next day, during which the landslides occurred.

The field observation indicated that all the landslides had started as translational slides even though some of them evolved subsequently into mud flows (Varnes, 1978). The slipping planes occurred along the discontinuities separating the saturated overburden from either the unsaturated (or drier) materials below or highly weathered bedrock from less weathered (or unweathered) bed rock (Fig. 3).

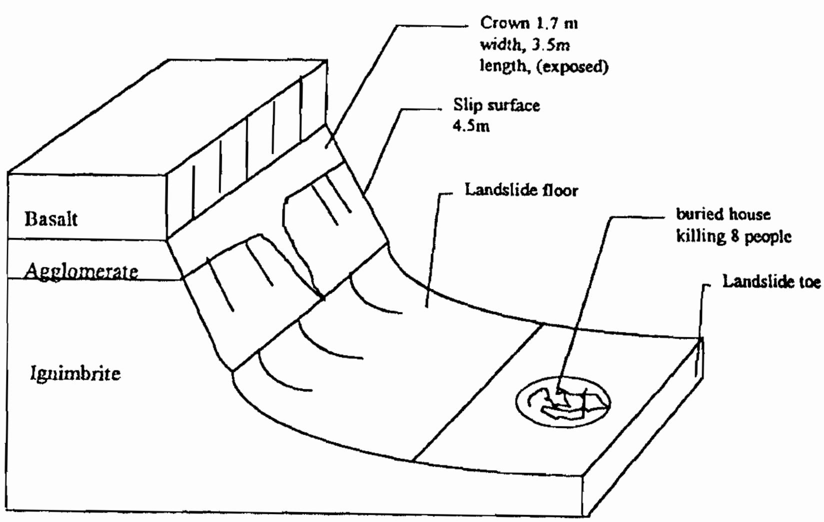

Fig. 3 Free hand sketch showing the nature of landslide 2 which caused the death of eight persons. Not to scale.

The particularities of each landslide are described below and are summarised in Table 1. The locations are shown in Fig. 2.

Table 1. A Summary of the main features of the June 18, 1996 landslides (Dabicho Ridge, Eastern Wondo Genet escarpment).

	Materials	Mechanism	Sliding plane angle	Dimensions (m)	Effects
Landslide 1	colluvium and weathered ignimbrite	translational sliding	45°	10x6x2	uprooted "enset" plants
Landslide 2	colluvium, weathered and fractured ignimbrite, and agglomerates	translational sliding to mud flow	45°–50°	12x17x1.5	destroyed a house causing 8 victims, uprooted and moved "enset" and "chat" plants, engulfed fields
Landslide 3	colluvium and weathered ignimbrite	translational sliding to mud flow		11x8x1	no major effects
Landslide 4	colluvium on massive ignimbrite	translational sliding to mud flow	very steep	25x7x0.5	stopped at 100 m distance before settlements

Landslide 1

It occurred in a cultivated area at the foot of a scarp, just above a peasant house. Here, a wedge of overburden consisting of colluvium mixed up with scree and boulders of decimetric size, and weathered materials, has slipped over a weathered ignimbrite bed rock. A spring appeared at the contact of the overburden and the bed rock. The exposed landslide scar has a slope of about 45°, a length of 10 m and a maximum width of 6 m. The landslide crown has an average height of 2 m.

The landslide has moved and carried away shallow rooted trees and twenty "enset" plants. A farmer's house which was originally built on the slide site had been dismantled earlier and rebuilt 5 m down slope. As a result there has been neither damage to property nor loss of life.

Landslide 2

In this site an overburden layer of 50 cm – 1.5 m overlies on a slope composed of ignimbrite, agglomerate and basalt, from the bottom to the top. The ignimbrite has a thickness of 4.2 m and is highly weathered. An agglomerate of thickness 1.7

m overlies the ignimbrite. The basalt which is affected by a system of joints having dominantly north-south orientation, has a thickness of 3 m.

The landslide (Fig. 3) took place on Tuesday morning at about 7 a.m., starting as translational slide from the contact between basalt and agglomerate, then turned into mud flow. The slipping plane is parallel to the slope and dips 45–50°. The scar is 12 m long at its maximum and 17 meter wide. Just above the landslide site, there is an irrigation ditch across the slope.

This landslide uprooted and moved several "enset" and "chat", engulfed fields and destroyed a house, causing the death of eight persons.

Landslide 3

A few meters east of landslide 2, a shallower and smaller landslide (10.8 m by 8.10 m) had occurred on the same day and, probably, at about the same time. Initially, it was a translational slide but after about 10 meters, being saturated of water, it turned into mud flow. The thickness of the overburden, overlying the slope of weathered ignimbrite is about 1 m. At the toe of the landslide there is a deposit of colluvial materials with a convex shape (Fig. 4). Here, a peasant's house, though not affected, has been abandoned after the landslide event.

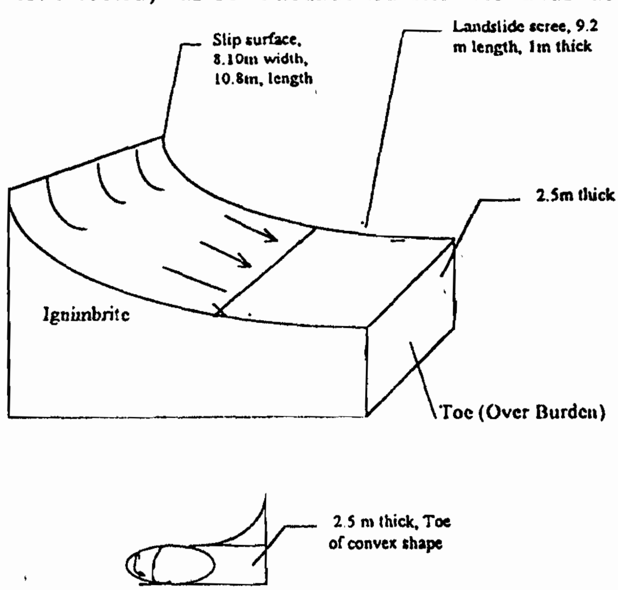

Fig. 4. Free hand sketch showing landslide 3. Not to scale.

Landslide 4

It actually consisted of a group of smaller landslides which occurred, as the others, on the same day, no much later than landslide 2. They were located on the eastern side of a deeply cut valley, some 300 m to the east of landslides 1 and 2, at about the same altitude. All these phenomena started probably as translational slide of soil materials over massive thick beds of ignimbrite, since in one of them the exposed bedrock shows a well defined slipping plane. The scree from these landslides has moved down into the valley floor and stopped some 10 m on the up slope side of a group of houses. Local people reported the emergence of a new spring and piping, which added more water to overland flood flow. At one place, a peasant's house and kitchen had been completely flooded up to 50–70 cm.

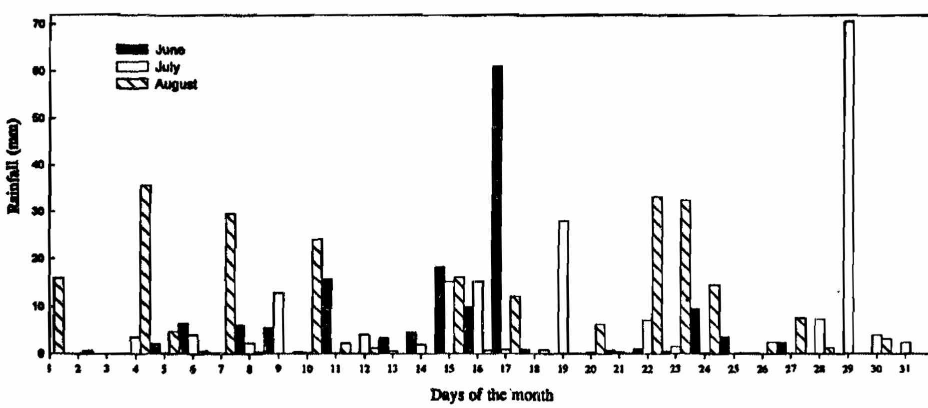

Fig. 5. Daily rainfall data for June, July and August 1996 of Wondo Genet area. The first peak was that of June 17 causing the land sliding phenomenon.

DISCUSSION AND CONCLUSION

Geological-geomorphological field investigations has allowed to determine mechanisms of the June 18 landslides at Dabicho Ridge.

It is almost certain that the triggering factor was the highest rainfall (61 mm) which occurred on June 17 (Fig. 5). This was the first 1996 high rainfall. Although other rainfall peaks followed later, similar landslides as that of the June 17 did not occur in the area. Possible explanation for this could be that landslides function episodically through destabilisation and stabilisation processes. The most vulnerable slopes became affected by the earliest rainfall while the remaining were momentarily stable even under similar or higher later rainfall conditions. This shows that a threshold of slope instability was reached by the time the heavy rainfall had led to a series of landslide phenomenon on the slopes of the Dabicho ridge.

Other factors have contributed to predispose the gravitational movements. Among them, the most important are the following:

i) the presence of thick (about 1.5 m on average) eluvial-colluvial covers which were easily saturated by the rain water, increasing pore pressure and reducing strain. This condition is indicated by the appearance of numerous ephemeral springs which produced heavy flooding in different areas before and after the landslide occurrence;

ii) the step-like profiles of the slopes due to both selective erosion and the effect of past landslides: the easier infiltration of water in the flat areas up slope favoured the triggering of landslides from the down slope scarp;

iii) the type of land use, including intensive cultivation (mostly "enset" and "chat") and irrigation ditches across the slope, which favoured even more the infiltration of rain water (as for the case of landslide 2); moreover, shallow rooted plants like "enset" and "chat" on steep slopes, increasing the weight of the overburden, may have favoured the detachment of saturated material.

As regards the risk connected to landslide hazard in the area, a particular consideration should be given to the location of settlements which, in many cases, have been built up on flat and gentle areas, often corresponding to old landslide scree deposits and at the base or at the edge of steep unstable slopes. That was, in fact, the situation of the eight victims' house.

In conclusion, based on the June 18, 1996 landslide event which was a result of the coincidence of the triggering factor (rainfall) with the predisposing conditions (geotectonics, geomorphology, climate and land use - land cover) it seems possible to define the eastern escarpment of the Awassa basin as an area characterised by high landslide hazard and risk for people, settlements and properties.

In order to assess the regional landslide distribution, their various causes, impacts and risks as well as to propose mitigation measures, the following initiatives are recommended:

- Make detailed geological - geomorphological maps at a scale of 1: 25,000 of the Wondo Genet area in order to delineate potential landslide zones;
- Undertake soil and rock analysis for their engineering properties and collect hydrogeological data;
- Produce regional hazard and risk maps;
- Modify the existing land use system, such as the type of farming in the area. It is suggested that deep rooted trees should preferably be planted, and proper irrigation systems be designed;
- Design safer settlement locations, possibly gathering houses in low hazard sites.

ACKNOWLEDGEMENTS

The authors would like to thank the Ethiopian Science and Technology Commission for providing a grant to study the Wondo Genet area. The Italian Cooperation through the grant to Prof. Dramis and the EU project STD3-TS3-CT92-0676 through a grant to Prof. Getaneh Assefa, have facilitated the field work during the landslide event. We would like to extend our gratitude to the Department of Geology and Geophysics, Addis Ababa University for its institutional support. Local people in the Wondo Genet area were very helpful in providing us with detailed information. Finally we are grateful to the constructive suggestions of the anonymous reviewers.

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