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September 1997-September 1998 was to have been the final year of grant NAG5-2584, however, no funds were received from NASA for this final year of funding. Hence this report is submitted as the final report summarizing progress up to November 1997. The grant supported Samson Tesfaye complete his Ph.D. thesis at the University of Colorado. Using remotely sensed data and GPS observations we completed a study of neotectonic processes responsible for landscape changes in an area of active extensional deformation and volcanism. The findings from this study describe the extensional processes operating in the region of the Afar triple junction and the northern Ethiopian rift.

Neotectonics of the Afar depression rift systems

The Afar triple junction has been a site of interest in extensional tectonic investigations and numerous studies have been conducted to understand its evolution. It is a site of a rare display of sub-aerial extension (normal faulting) and volcanism commonly found in the ocean floors. The relatively young age of Afar and the prevailing arid climate extension (normal faulting) and volcanism commonly found in the ocean floors. The relatively young age of Afar and the prevailing arid climate have preserved the marks of the tectonic and volcanic process that acted on the region. The good exposure of rocks coupled with lack of vegetation cover makes Afar an ideal place to use remotely sensed data for geologic investigations. This research uses remotely sensed images to investigate the extensional process that have operated in the area, and GPS measurements conducted in the region 1992-97.

Three manuscripts describe fault geometries and scaling relations, and the structural development of central Afar are attached as an Appendix to this report.

Structure and morphology of Afar

The work conducted thus far indicates that the computation of extension from digital imagery may not be possible for the entire region. One of the reasons for this is that sediment covers much of the graben floors, masking lower faults whose scarps (fault throw) are essential in the computation of extension. We were concerned that the coarse spatial resolution of the DTED data might limit our assessment of scarp heights, for example, essential in the computation of cumulative extension. Field observations confirmed our suspicions about the incompleteness in spatial sampling, but both were useful in confirming our remote interpretations in several locations, and provided data on the applicability of self similarity laws that permitted us to estimate the importance of these missing data.

GPS measurements in Afar and the Northern Rift

The Northern Ethiopian Rift is believed to be floored by a continental lithosphere. Works by Makris and Ginzburg, 1987 and Mohr, 1989 indicate that the lithosphere beneath Afar is different from both continental and oceanic lithosphere. From our current studies we have weak evidence to suggest that the style and geometry of the faults, and the magnitude of throw associated is influenced by the underlying extension process. But the most important new input comes from GPS investigations partly funded by the current project and by an ancillary NSF project.

In the period 1969 to 1976 Paul Mohr, then at the Smithsonian Institute, installed a series of points throughout the northern rift and also in Afar, whose relative positions were measured with geodimeters. We have measured several of these points with GPS in 1992 and also in 1995 and in 1997. The data from the northern rift indicate that extension occurs at 3±1 mm/year and that it is localized in the deepest and most recently faulted part of the rift (Figure 2). The data span a distance of 120 km but most of the widening is concentrated within a zone less than 40 km wide where the strain rate peaks at 0.1±.02 μstrain/year. Significantly this rate is similar to that encountered across the central part of transform faults, like the San Andreas system, and regions of convergence, like the Himalaya.

Models designed to emulate the strain-field cannot be constrained by detailed information of the subsurface geometry because this is unavailable, and so we use the simplest possible model for extension, that of a buried, extending-vertical fault centered on the strain-field. The resulting strain-field is equivalent to magma injection of a vertical dike in the subsurface. Clearly this is a simplification for the process that is actually occurring but it provides us with an extreme boundary condition to guide further research.

The best fitting models of the process reveal suggest that the top of the "dike" is 8±3 km deep and that the adjoining lithosphere is 100±30 km thick. The ratio of the thickness of adjoining lithosphere to that at the base of the rift is 20±5 - a surprising result not predicted from seismic studies. Seismic estimates of the thickness of the lithosphere indicate depths of 10-15 km in the central rift, perhaps biased by the relatively large wavelengths used to estimate travel times in the rift zone. A narrow dike, or several dikes in parallel, would be invisible to these seismic refraction studies, and certainly to seismic tomography, so that our result is consistent with these studies

Tidal strain enhancement across the African Rift?

To explore this interesting geometrical result further we established two GPS stations on either side of the rift running continuously. The remote site is on the eastern escarpment and is in radio contact with Addis Ababa, on the western escarpment, 120 km away, where data from the two sites are archived daily. We receive 30 s data regularly for analysis.

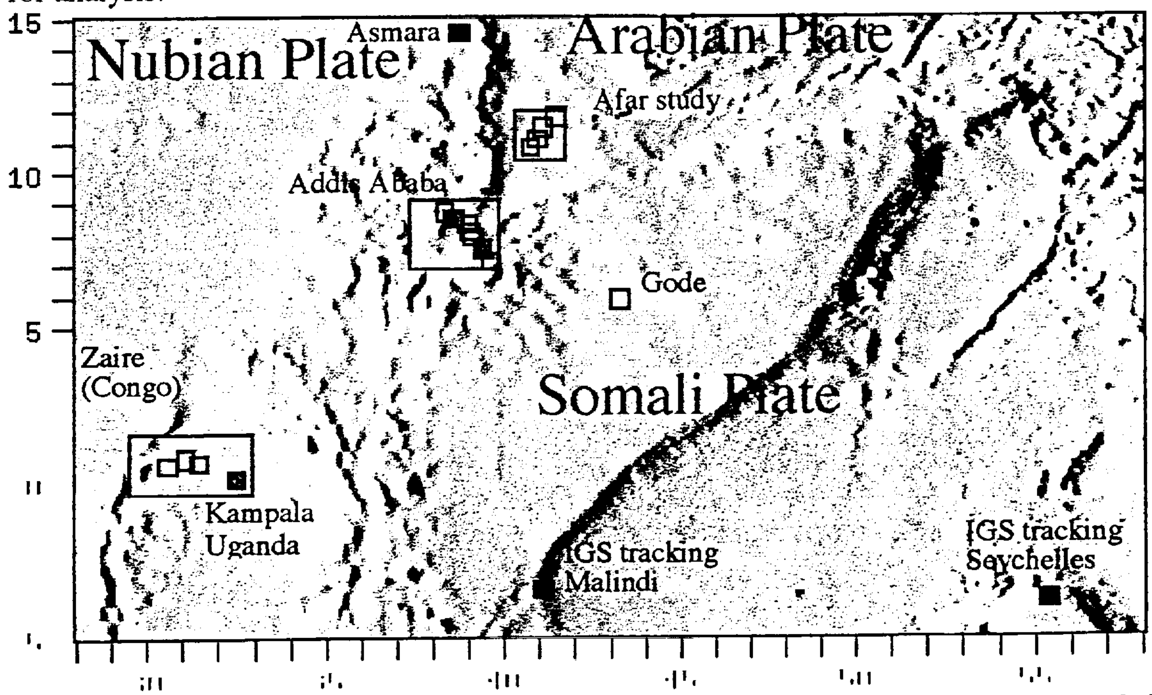

Fig.1 Location of GPS measurements in East Africa, and existing tracking sites in Malindi and the Seychelles. Approximately 32 points are contained within the three boxes. The Nubian/African plate boundary is typically diffuse, but in some locations, like the northern Ethiopian rift, it is clearly expressed (see Fig.2). We have requested red points be adopted by NASA as FLINN sites to free up our GPS receivers for this NSF project. The green point is our continuous point REDG on the eastern side of the rift.

We hypothesize that if our secular signal is correctly interpreted, the African rift consists of a major rheological discontinuity in the thick Archaen crust of Africa. It acts like an enormous fissure separating two rigid blocks. The kinematics of such a system are that any strain applied to the system is manifest as displacement across the "fissure" . The fissure acts as a giant displacement amplifier. The Earth tide is a periodic signal applied to Africa and is presumably amplified across the rift zone. The degree of amplification is approximately given by the geometry of the fissure. In our case the geometry is given by the ratio of elastic thickenesses of the lithosphere inside and outside the rift - viz. 20!

In practice, amplification is reduced from that given by the geometric ratio, by the ratio of compressional and shear rigidity modulii in these two regions. For compressional and extensional strain the ratios may be close to unity. For shear strain, however, the presence of partial melt in the volcanic systems of the rift suggest that amplification may be quite significant. By observing amplification of the Earth tide we can, in principle, develop models for the rheology of the rift and underlying upper mantle. This is not only an important new breakthrough for rift studies, but it provides an innovative application for GPS arrays.

The Earth's body tide consists of two components, a dilatational signal and a shear signal. The theoretical amplitude of each of these semidiurnal strain tides is roughly 5E-8, or 6 mm in 120 km, the separation of the two receivers. We plan to analyse this semidiurnal and diurnal signals using kinematic GPS analysis techniques. At the time of writing we had not received sufficient Ethiopian data for analysis, but at our suggestion a successful pilot analysis was performed in Boulder by Yuki Takanaka, on data from the continuous Japanese network. The details of the analysis are as follows. Kinematic solutions for a pair of sites are obtained for 30 sec samples based on improved orbital data obtained from 24 hour analyses of global tracking sites. As satellites approach the horizon the kinematic solutions become increasingly noisy. These outlying data are carefully removed from the solution leaving only segments of data with quality solutions with scatter at the cm level. The data are now formed into 3 hour running means to reveal the tide. Spectral analyses techniques show a complete absence of O1, S2 and K1 spectral lines, but with a 2 cm M2 tide within 10% of the predicted load tide signal. An important aspect of this analysis is that it was conducted on the noisy vertical GPS signal. In Ethiopia we anticipate that the horizontal components will show the largest signal amplification.

Implications of tidal amplification in rift zones

Although we have yet to demonstrate tidal amplification, we here speculate on a possible consequence of an amplified rift tide. We set aside for a moment the degree of amplification that we seek at diurnal and semidiurnal frequencies (this is known as the tidal admittance). Clearly this signal in principle contains information about the geometry of rheologic contrast, and its frequency dependence. Even a null result for tidal admittance (unity at all frequencies and for all species of tide) is of interest in constraining rift zone properties.

Consider for a moment a wide zone of partial melt subjected to a sinusoidal *shear* displacement of 6 mm twice per day - the semidiurnal tide. The peak shear strain rate depends on the width to which this shear displacement is applied. For the entire 120-km-

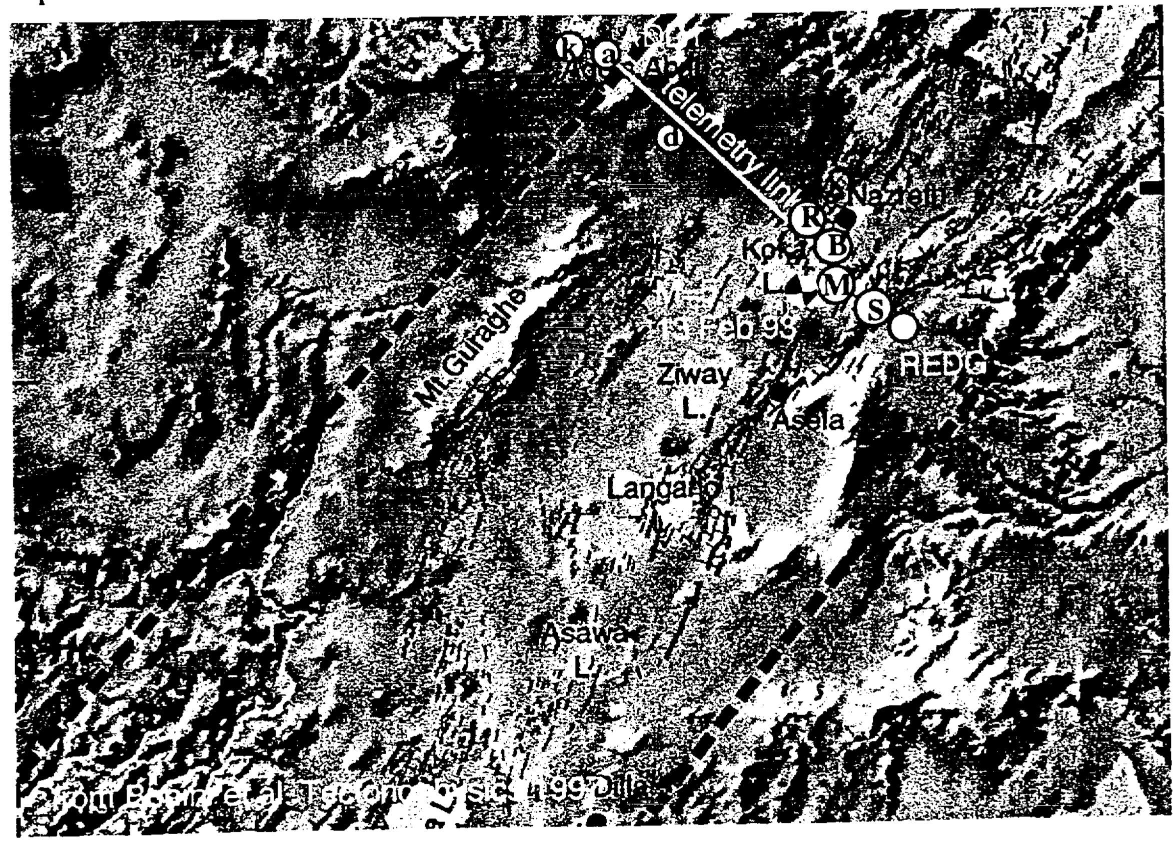

Fig.2 Detailed view of the northern Ethiopian rift. White points are GPS measurements 1992-1997, and yellow points are geodimeter/GPS measurements 1970-1997. Radio telemetry conveys data from REDG to Addis Ababa, where GPS data are recorded continuously along with data from ADD1 (a). The focal mechanism and location of the 1993 M=5 earthquake is shown.

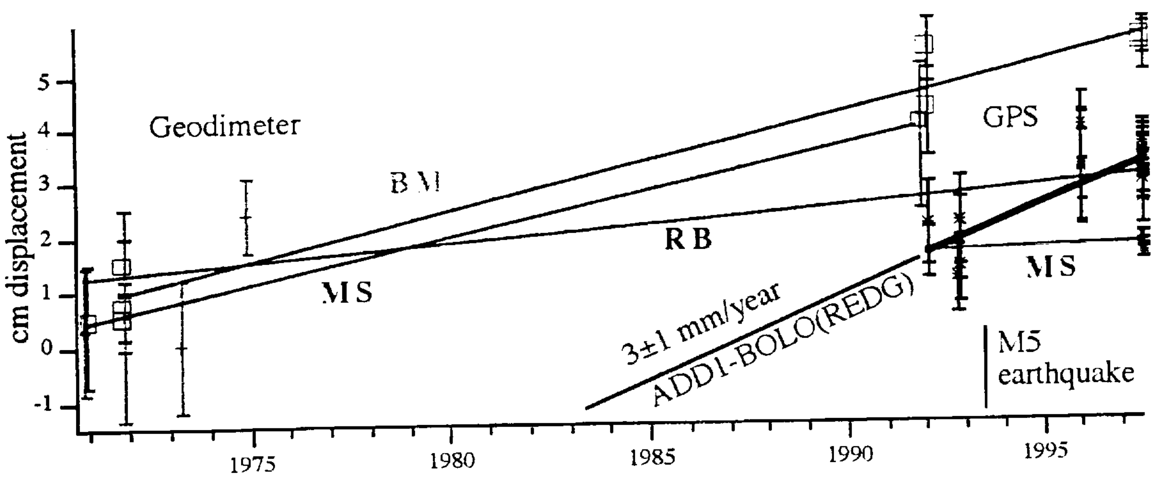

Fig. 3 Geodimeter and GPS data 1970-1997. Recent GPS data (black markers & line) define the 140-km -wide, rift-widening rate. Short (<15 km) hybrid GPS and geodimeter lines are shown as colored lines corresponding to lettered points indicated in Figure 2. The slope of each line corresponds to the rift widening velocity between the appropriate lettered points in the rift (weighted least squares fits). The sum of the velocities RB+BM+MS (2.9±0.6 mm/year) is roughly equal to the ADD1-REDG velocity (3±1 mm/year). No strain is detected outside the zone R to S. The late 1995 GPS data were undertaken at no cost to us by collaborators who used no ground planes (!) on the Trimble antennas during the survey.

wide rift zone this represents a strain rate of $5*10^{-8}/12$ hours (10^{-7}/day or 10^{-12}/s) . However, our 1992-97 data indicate that the secular signal is concentrated within a gaussian half-width of 12 km. In this case, the semidiurnal strain signal, assuming an absence of frequency dependent non-linear rheology, causes a strain rate of 10^{-11}/s. Following this reasoning to the even narrower zone permitted by our elastic modeling of the secular signal, the strate rate that could result from a single, fluid-filled "dike" less than 12 m wide could exceed more than 10^{-8}/s. In deriving this strain rate we are assuming that the entire strain field for a 120 km wide zone is concentrated into a 12 m dike. It is possible to invoke yet larger strain rates by narrowing the dike or by increasing the effective depth of weakened shear rigidity to below 100 km, or smaller rates can be envisaged by widening the dike or by assuming that viscosity at 12 hour periods effectively attenuates the geometric amplification inferred from the secular (5 year GPS and 25 year geodimeter signal).

High strain rates in a viscous fluid have the potential to heat the fluid. A strain rate of 10^{-8}/s is classed by Spray (1992) as a "high" isothermal strain rate for ceramic materials potentially leading to melt conditions. High strain rates melt rock, for example, in the frictional heating of fault zones during fault-slip causing the formation of mylonites. If we imagine a cooling dike subject to a shear strain it will effectively reach a width where strain-rate heating balances conductive cooling, preventing the dike from freezing.

In general, then for a large two-dimensional dike separating thick lithosphere in the presence of a diurnal or semidiurnal tide, a dike, once formed might never cool. In a three dimensional world it is difficult to suppose that local cooling will not cause the tips of the dike to lock near the surface, and along-strike, such that strain-concentration effects are reduced and eventually eliminated. However, the proposed mechanism is sufficiently intriguing for us to take it seriously as a mechanism for maintaining the rift as a linear zone of weakness for many millions of years. It is possible to speculate that tidal shear heating could even be responsible for driving a rift through a continent initially. Any local strain concentration could act as a positive feedback mechanism for strain concentration, feeding enhanced strain thereby, increased shear-heating into an ever-decreasing region until melting occurs. Once formed the tip of the melt zone would experienced the largest shear stresses and would naturally propagate, sustained by tidal frictional heating.

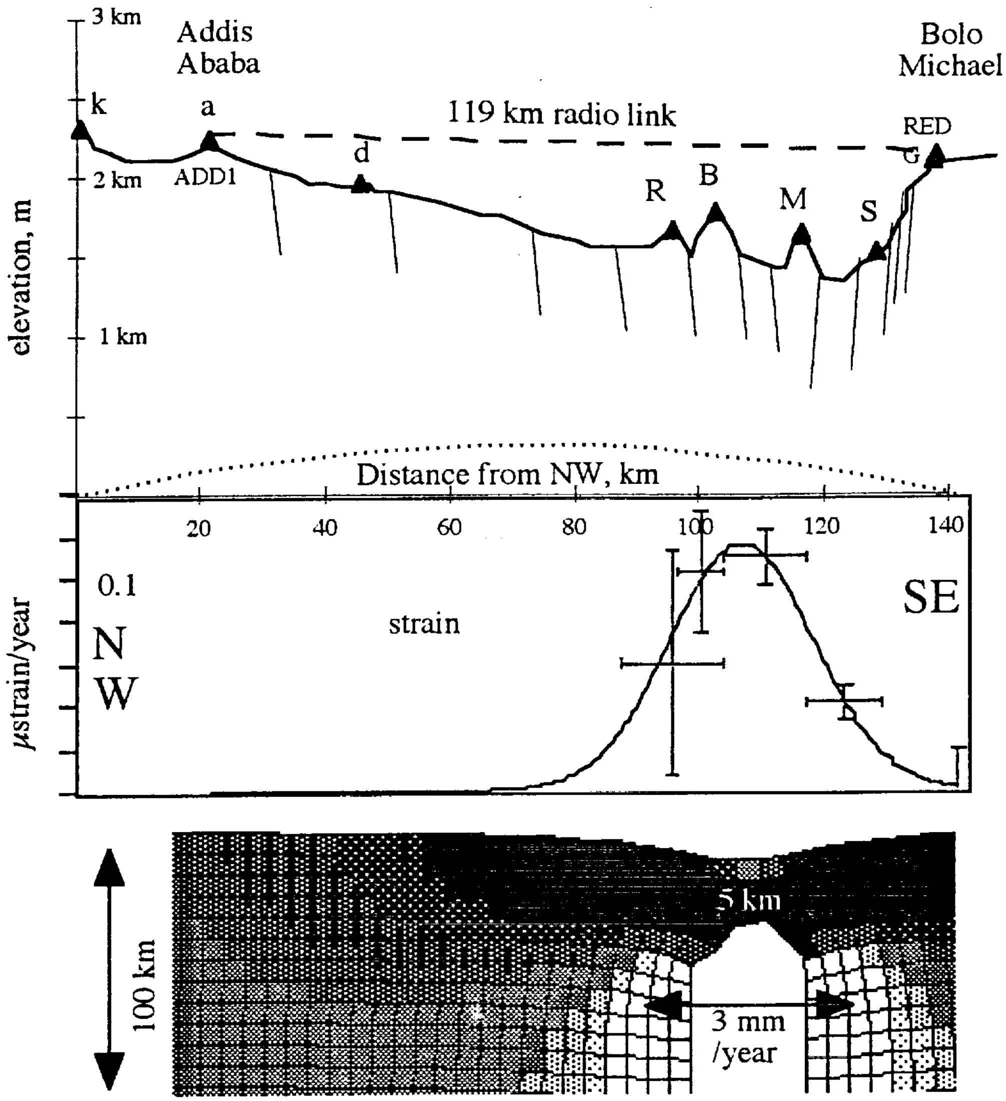

Fig 4 Topography, faulting-density and strain-rate observed across the northern rift (dotted line is Earth's curvature to same scale). The bottom panel shows a boundary element model for dilatational strain and surface subsidence caused by a simple vertical dike that emulates the strain field. Black indicates tensile strain. White indicates contraction.

Potential future applications of GPS rift studies

We would like to examine other rift zones in Africa and elsewhere (Danakil, Red Sea, Iceland, Baikal, Rio Grande) for potential strain amplification. Such experiments, like the current northern Ethiopian study require continuous GPS measurements *for a limited period only.* In previous exeriments in tidal strain measurements (Bilham et al. 1974) we found that 6 months is the longest one would typically require data to separate solar and lunar periodic functions from each other. Such independence is necessary to isolate solar driven diurnal heating effects in the atmosphere and solid earth, from the lunar components whose amplitudes are influenced only by rheology and its geometric distribution. In contrast to these proposed future studies, continuous GPS arrays, like seismic arrays, must be operated continuously *for ever* to be of value in distinguishing events from secular deformation. One of the curious aspects of the African rift is the gross geometry of the rift system as a series of discontinuous segments disposed at 30° azimuths. Unlike other plates, Africa has been relatively immobile relative to the mantle for an extended period

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Ethiopia Rift Measurements July 1997
Field Report September 1997

Eight points previously measured by GPS methods in 1992 across the northern Ethiopian rift near 8°N were re-measured in July 1997. The remeasurements show that widening of the rift is 3.7±0.9 mm/year, and that most of this widening is concentrated in the deepest, most youthful part of the rift zone (2.9±1 mm/year). Masonry monuments were constructed over bedrock points separated by 119 km on the edges of the rift and a telemetry link installed to bring these data to the Geophysical Observatory for analysis. Data from these two sites are recorded 24 hrs/day to monitor rift widening and shear strain across the rift. They will also be used to search for possible amplification of periodic shear or dilatational strain signals applied to the rift zone at tidal and seismic frequencies. The proposed analysis of tidal amplitudes will permit us to estimate rheological conditions in the upper mantle, and will permit us to assess the contribution of tidal shear strain to rift volcanism. Additional GPS points were installed near Gode in Ethiopia and west of Kampala in Uganda.

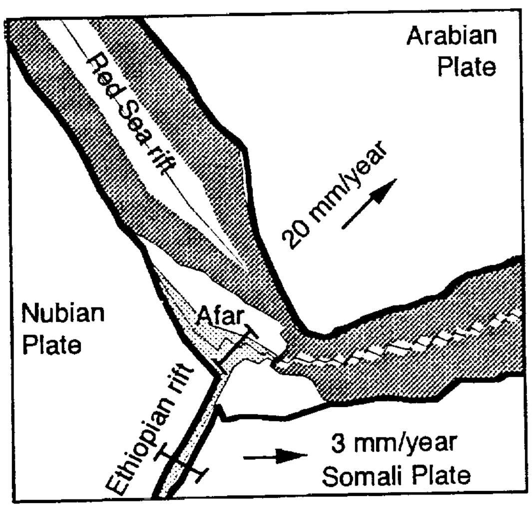

Fig.1. The Afar triple junction showing locations of the GPS arrays across Afar and the Ethiopian rift, and estimated velocities relative to the Nubian plate.

Introduction

In January and again in November 1992 scientists from EIGS[1], EMA, the Geophysical Observatory of Addis Ababa University, and from CIRES, the University of Colorado, measured the relative positions of approximately 20 points across the northern Ethiopian Rift and across the Afar depression to an accuracy of ≈3 mm. The objective of the measurements was to measure directly the rate of widening of these two rift zones.

By measuring at points that had been established 20 years earlier by the Geophysical Observatory in Afar (Mohr, 1970) it was possible immediately to learn something of the recent activity on these rift zones. Thus in 1992 we established that the Dobi graben had widened approximately 30 cm since 1970. Although this is probably associated with the 1989 swarm of M≈5 earthquakes that activated normal faulting throughout the graben, the measurement corresponds to a mean opening rate of 15 mm/year, 75% of the mean widening rate for the Red Sea rift obtained from global plate studies.

[1] EIGS=Ethiopian Institute of Geological Surveys, EMA=Ethiopian Mapping Authority, CIRES=Cooperative Institute for Research in the Environmental Sciences.

Surprisingly, no widening (1±1 mm/yr) was detected in 1992 in the main Ethiopian rift zone near Addis Ababa, where control points had been first measured in the interval 1969-74 (Asfaw et al. 1992). Various reasons for the null result were proposed: the opening rate was perhaps less than the ±2 mm/year detection threshhold of the measurements, rift widening perhaps occurs only during seismic activity, rift activity may have occurred outside the 48 km central part of the rift measured, or perhaps the rift zone is currently acting as a strike-slip system of faults. The measurements in 1997 show that the 1992 estimate was contaminated by what we now infer to be a spurious measurement at the point Ganti toward the SE, resulting in an apparent contraction of the line Ganti-Mietchi. The 1992 estimate of widening was based on three non-contiguous lines (Figure 2), and a fourth that was not compared because it was to an auxillary point at Boku. The 1992 and 1997 observations of this point, when adjusted correctly for the eccentricity of the 1970 geodimeter measurement shows consistent elongation, indistinguishable from a linear strain rate. The strain rate we obtain for the Boku-Mietchi line is of the same order as strain of contiguous lines in approximately the same azimuth, and since the Boku-Mietchi line and the Ganti-Mietchi line differ in azimuth by less than 20° we infer instability of the Ganti point is responsible for its apparent contraction 1970-1992. The point was destroyed by villagers soon after our measurements in 1992.

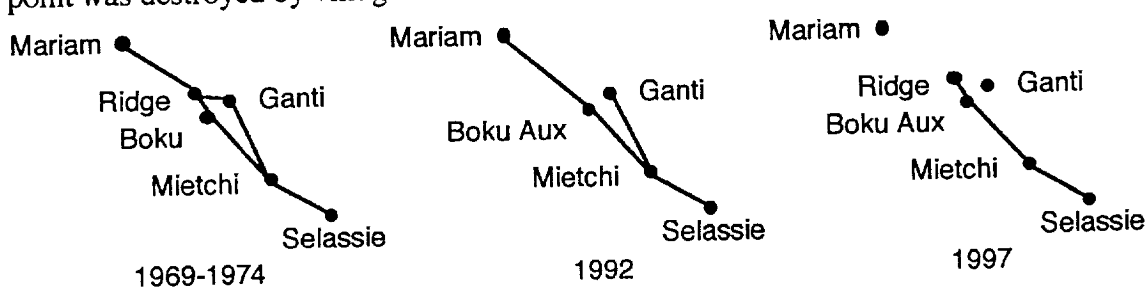

Figure 2 First epoch measurements of the central rift were completed in 1970 using geodimeters (Mohr et al, 1976). In 1992 and 1997 some of these lines were remeasured using GPS methods. The line Ganti-Mietchi alone shortened presumably due to spurious motion of the point Ganti which is now lost. Mariam remains but could not be measured because of an army camped above it in 1997.

Because the 1970's geodimeter points we occupied in 1992 formed lines with azimuths normal to the trend of the rift, their comparisons with 1992 and 1997 line-length data are almost completely insensitive to rift parallel displacements. Some authors have proposed that shear strain may be significant in the Ethiopian Rift (Bonini et al, 1997). The 1992-1997 GPS data in principle permit the resolution of rift-normal and rift-parallel strain, however, the crucial observations across the rift in 1992 (KOLO, ADD1 and BOLO with several day occupations) were undertaken during a time of anti-spoofing (AS code implementation), and consequently we were unable to obtain improved orbits in our estimates of 1992-1997 east and north motions. The data we have processed suggest that east and south components of displacement are somewhat similar, i.e. that the rift apparently opens normal to its margins. Current uncertainties permit 2±2 mm/year of sinestral slip in addition to the 3.9±0.6 mm/year opening rate in a SE direction.

The 1997 remeasurements of 1992 points: Kolobo, Addis Obs. (ADD1 & ADD0), Dukam, Ridge (near Nazret), Mietchi (Dera), Selassie (NW of Sire) and Bolo Michael (East of Sire) were completed with 6 receivers in 8 days with occupation durations of 3-10 days. The point Ridge was measured for the first time with GPS in lieu of a nearby point currently inaccessible to us (Mariam, east of Mojo, which is now beneath a temporary army telemetry post). The Dukam point we occupied is one of the 4 French points of that name and the point we occupied was 11.26 m from our 1992 point requiring an eccentricity estimate before comparison with the 1992 data.

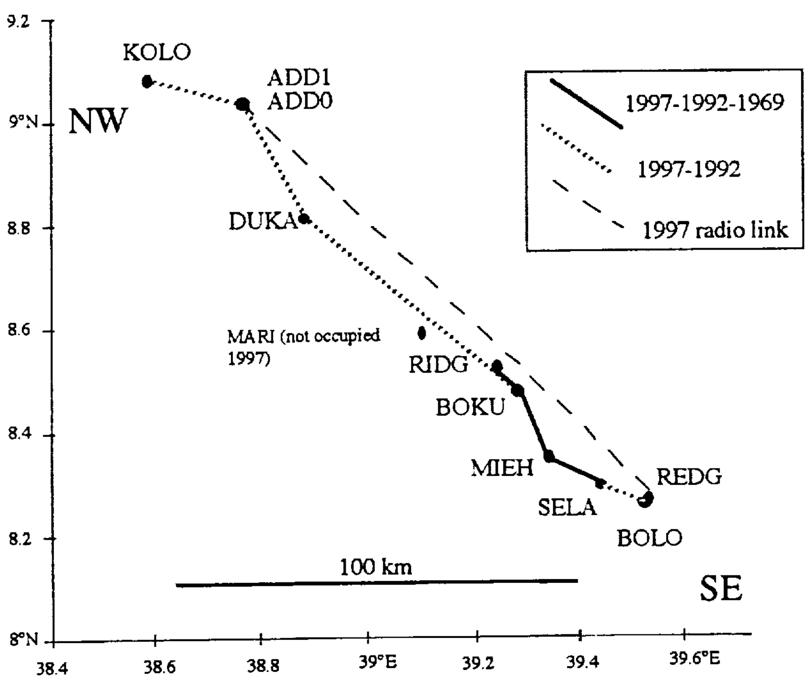

Fig.3. Points measured across the Northern Ethiopian Rift in July 1997, and the new fixed GPS link ADD1-REDG.

Remeasurement Guide

Jan1992	Nov1992	July1997
ADD0/1	ADD0/1	ADD1/0
DUKA		DUKA
BOKU		BOKU
MIEH		MIEH
SELA	SELA	SELA
	BOLO	BOLO
	KOLO	KOLO
MARI(inaccesible)		REDG
GANTI(lost)		GODE
		RIDG

Summary of stain changes and velocity field observation

Figures 4-6 show least squares fits to all available data from geodimeter and GPS occupations as of 6 Sept. 1997. The weighted least squares fits to the data are summarized in NW /SE rift profiles of strain and velocity. These summary plots are composite plots merging GPS and geodimeter data. The 27 year data sample yields displacement and strain rates 2-3 times more precisely than do the GPS only data for the past 5 years, but they are confined to the most active 25% of the width of the rift. The combined line length increase between Ridge and Selassie is 2.9 mm/year with an uncertainty of 1.6 mm/year or 0.8 mm/year if all the errors are uncorrelated. The Addis-

Selassie line extended 3.1±0.9 mm/year 1992-1997, and the Addis-Bolo line extended 3.7±0.9 mm/year 1992-1997, suggesting that little additional deformation occurred outside the zone of deformation monitored by the geodimeter lines. Additional data are needed to establish how much of the residual deformation occurs between Selassie and Bolo (unlikely), and between Ridge and Addis Abeba. Eccentricity measurements at Dukam may permit Dukam to be utilized to improveour knowledge of the distribution of strain between Addis abeba and Ridge.

GPS Telemetry - an electronic ruler across the rift

Two permanent GPS receivers were installed to improve the rift widening estimates and constrain the azimuth of maximum rift separation. The points are 119 km apart in Addis Ababa (ADD1) and Bolo Michael (REDG) respectively, and operate 24 hours/day. Continuous observations permit improved tropospheric modeling, and the estimation of seasonal effects on the data, and in principle permit us to achieve 1 mm/year positioning accuracy. Masonry pillars were built at each location and a spread-spectrum radio link used to relay data from each Trimble 4000SSI receiver to the observatory without disturbing data acquisition. The line-of-sight radio link crosses the entire rift zone without repeaters. Data from these two sites are recorded every 30s with a 15 degree window resulting in 3 Mb/day of data (90 Mb/month). Data downloading takes 15 minutes via radio. The data are archived on 100 Mbyte removable ZIP disks stored in the observatory.

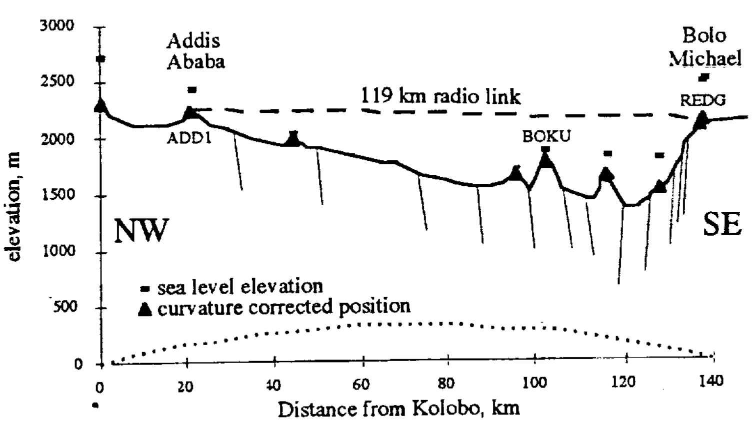

Fig 7. Profile along the GPS line of Fig.2 corrected for the Earth's curvature (dashed curve). Point REDG if used as a repeater has line-of-sight access to most of the rift zone.

A point was installed remote from the Ethiopian rift near Somalia at Gode, and at four points in Uganda to provide estimates of plate deformation and the rotation rates between blocks adjoining the rift. The 513 km distance from Bolo Michael to Gode potentially yields a rotation precision of 8 nanoradians/year for the Somali block.

Receiver Geographic Positions (See next page for precise ephemeris ITRF92 and WGS84 frame coordinates calculated using GIPSY.

GPS Sites occupied in July 1997, ETHIOPIA

	long dec	lat dec	el.m	lat °	lat'	lat"	long°	long'	long"	m	code	long
KOLO	38.58369	9.08111	2709	9	4	52	38	35	1.3	2709	KOLO	Kolobo Village (W of Addis)
ADD1	38.76608	9.03528	2436	9	2	6.99	38	45	57.9	2436	ADD1	Addis Main Point 1992
ADDO	38.76625	9.03493	2436	9	2	5.73	38	45	58.5	2436	ADDO	Addis Small Pillar
DUKA	38.88364	8.81289	2047	8	48	46.4	38	53	1.1	2047	DUKA	Dukam Auxilliary Point
RIDG	39.24353	8.52219	1710	8	31	19.9	39	14	36.7	1710	RIDG	Ridge W. of Nazret (Mohr)
M=5	39.308	8.331										
BOKU	39.28233	8.47211	1863	8	28	19.6	39	16	56.4	1863	BOKU	Boku (Mohr) SE of Nazret
MIEH	39.33742	8.34611	1817	8	2C	46	39	20	14.7	1817	MIEH	Mietchi near Dera
SELA	39.43778	8.29139	1793	8	17	29	39	26	16	1793	SELA	Selassie Village
REDG	39.531	8.26556	2508	8	15	56	39	31	51.6	2508	REDG	N. of Bolo Michael village
BOLO	39.52019	8.25765	2477	8	15	27.6	39	31	12.7	2477	BOLO	S. of Bolo Michael 1992
GODE	43.56803	5.93111	260	5	55	52	43	34	4.9	260	GODE	Gode Main point
GOD2	43.56778	5.93083	260	5	55	51	43	34	4	260	GOD2	Gode Auxilliary 9 m S of Gode
GOD3	43.56158	5.91739	248	5	55	2.6	43	33	41.7	248	GOD3	Gode Secondary 1.6 km S of G

distances from Kolobo				km		m	m curve	±km	curvature correction (km)		
KOLO	0	0	0	0	C	2709	2322	-70	0.387	0.3872	-70
ADD1	0.182389	-0.0458	20.7		21	2436	2244	-49	0.192	0.1921	-65
ADDO	0.182556	-0.0462	20.7		21	2436	2244	-49	0.192	0.1919	-60
DUKA	0.299944	-0.2682	44.3		44	2047	1995	-26	0.052	0.0523	-55
RIDG	0.659833	-0.5589	95.1		95	1710	1660	25.1	0.05	0.0499	-50
BOKU	0.698639	-0.609	102		102	1863	1782	31.9	0.081	0.0807	-45
MIEH	0.753722	-0.735	116		116	1817	1651	45.8	0.166	0.1658	-40
SELA	0.854083	-0.7897	128		128	1793	1528	58	0.265	0.2654	-35
REDG	0.947306	-0.8156	138		138	2508	2148	67.5	0.36	0.36	-30
BOLO	0.9365	-0.8235	137		137	2477	2120	67.2	0.357	0.3566	-25

UGANDA

	declong	declat	el m	lat		"	long		"	el m		1997 Data
KABU	30.477	0.24	1677.1	0	14	24.1	30	28	36.4	1677.1	Kabuga, Uganda	181-184
KITE	30.715	0.9418	1393.3	0	56	30.5	30	42	52.6	1393.3	Kitehe, Uganda	180-182
KYEN	30.65	0.6413	1373	0	38	28.7	30	38	58.3	1373	Kyenjojo, Uganda	179-182
IBAN	30.036	0.3448	1635.7	0	20	41.2	30	2	11	1635.7	Ibanda, Uganda	183-187

Ethiopia positions July 1997 calculated 8 Sept 1997

The following positions were calculated by Kristine Larson using precise orbits. Their absolute positions are accurate to 10 cm and their relative positions (one to another) are accurate to approximately 1 cm horizontal and 2 cm vertical.

Ethiopia Positions July 1997, ITRF94
(International Reference Frame 1994)
absolute accuracy 10 cm in all three coordinates

ADD1	4913665.3315	3945901.0005	995400.6389
BOKU	4884809.7068	3995656.6800	933731.3982
BOLO	4871316.2271	4018483.8800	910342.9756
DUKA	4908226.9368	3958127.4352	971030.0564
KOLO	4925779.6875	3929903.8700	1000448.8505
MIEH	4882511.7496	4001618.7075	919934.4099
RIDG	4886768.3213	3991738.3873	939189.0715
SELA	4876132.9001	4010714.9717	913954.4508
GOD1	4596951.6915	4372688.9951	654710.1504
REDG	4870482.0790	4019341.6996	911217.1941

WGS84 -
HEIGHTS ARE ELLIPSOIDAL, NOT RELATIVE TO SEA LEVEL
absolute accuracy 10 cm in all three coordinates
relative positions within 1 cm horizontal, 2 cm vertical

ADD1	9.0352955446	38.7660788042	2438.1467606155	
BOKU	8.4721290826	39.2823393330	1860.3851542715	
BOLO	8.2576351630	39.5201676573	2477.5325655313	
DUKA	8.8128860044	38.8836469669	2044.5369219407	(RM1)
KOLO	9.0811179533	38.5836959689	2700.7611098504	
MIEH	8.3461146082	39.3374289105	1820.2445489438	
RIDG	8.5222070482	39.2435392281	1714.0352494195	
SELA	8.2915278158	39.4379672029	1788.3428764101	
GODE	5.9311343987	43.5677654209	256.8432751121	
REDG	8.2655811793	39.5309878067	2506.6868776418	