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The KRISP 90 seismic experiment—a technical review

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Abstract

On the basis of a preliminary experiment in 1985 (KRISP 85), a seismic refraction/wide-angle reflection survey and a teleseismic tomography experiment were jointly undertaken to study the lithospheric structure of the Kenya rift down to depths of greater than 200 km. This report serves as an introduction to a series of subsequent papers and will focus on the technical description of the seismic surveys of the main KRISP 90 effort. The seismic refraction/wide-angle reflection survey was carried out in a 4-week period in January and February 1990. It consisted of three profiles: one extending along the rift valley from Lake Turkana to Lake Magadi, one crossing the rift at Lake Baringo, and one located on the eastern flank of the rift proper. A total of 206 mobile vertical-component seismographs, with an average station interval of about 2 km, recorded the energy of underwater and borehole explosions to distances of up to about 550 km. During the teleseismic survey an array of 65 seismographs was deployed to record teleseismic, regional and local events for a period of about 7 months from October 1989 to April 1990. The elliptical array spanned the central portion of the rift, with Nakuru at its center, and covered an area about 300 × 200 km, with an average station spacing of 10–30 km.

Major scientific goals of the project were to reveal the detailed crustal and upper-mantle structure under the Kenya rift, to study the relationship between deep crustal and mantle structure and the development of sedimentary basins and volcanic features within the rift, to understand the role of the Kenya rift within the Afro-Arabian rift system, and to answer fundamental questions such as the mode and mechanism of continental rifting.

1. Introduction

The extensional tectonic structures extending through central Kenya have long been recognized as the classic example of a continental rift zone. Although the surface structure is fairly well known, its relationship to deeper features in the

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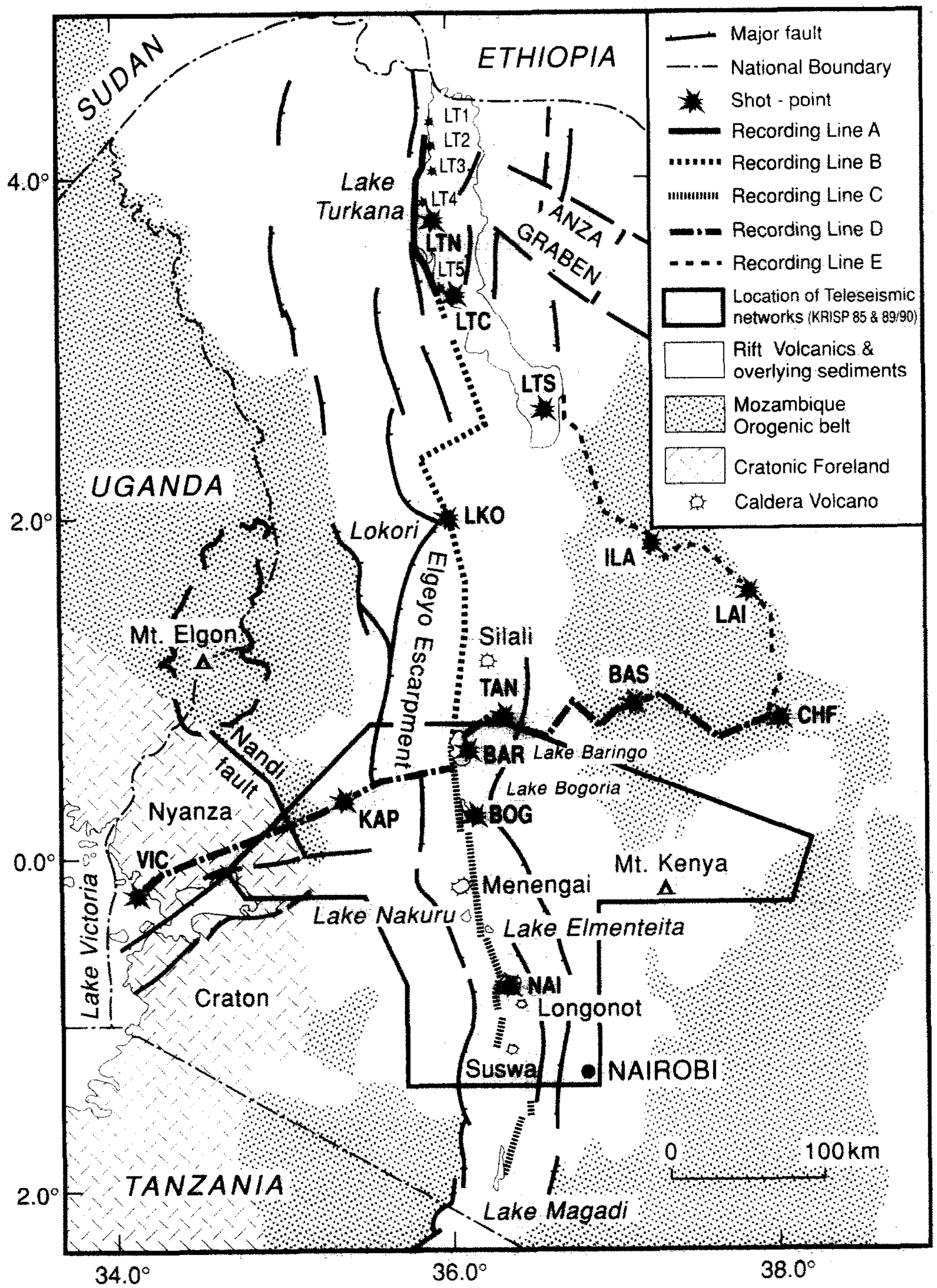

Fig. 1. Location map of the KRISP 90 seismic refraction/wide-angle reflection survey (lines) and the KRISP 85 and KRISP 90 teleseismic surveys (trapezoidal area).

crust and uppermost mantle is not. The purpose of the Kenya Rift International Seismic Project (KRISP) was to provide essential seismic data for determining the deep structure of the Kenya rift and to use this information to better understand rift processes on a global scale.

It was the objective of the main research programme, KRISP 90, to investigate the lithospheric and asthenospheric structure of the Kenya rift in detail in order to learn and understand the mode and mechanism of continental rifting (e.g., Gölke and Mechie, 1994-this volume), to study the relationship between deep crustal and mantle structure and the development of sedimentary basins and volcanic features within the rift, and to understand the role of the Kenya rift within the Afro–Arabian rift system (as summarized, e.g., by KRISP Working Party, 1991; Keller et al., 1994b-this volume).

In particular the integrated seismic project served:

(1) to study lateral heterogeneities in structure, physical properties and composition of the crust, with high resolution, in the rift (Mechie et al., 1994b-this volume) and on its flanks to the east and west (Braile et al., 1994-this volume; Maguire et al., 1994-this volume; Prodehl et al., 1994-this volume);

(2) to provide absolute velocities, needed for comprehending the material properties, by deeply penetrating seismic waves generated by the long-range refraction experiment foreseen in KRISP 90, while the teleseismic studies together with gravity data would provide relative geometries (see, e.g., Achauer et al., 1994-this volume; Ritter and Achauer, 1994-this volume; Slack and Davis, 1994-this volume);

(3) to penetrate into the upper mantle under the Kenya dome and probe its physical state and composition (Keller et al., 1994a,b-this volume; Achauer et al., 1994-this volume), in combination with petrological information from the mantle (Mechie et al., 1994a-this volume);

(4) to use the large explosions as seismic sources known precisely in time and space in order to calibrate the mobile seismic array (Ritter and Achauer, 1994-this volume; Tongue et al., 1994-this volume);

(5) to establish a high-quality crustal velocity model for P- and S-waves for earthquake location purposes (e.g., Tongue et al., 1994-this volume), and to provide this crustal model as a basis for the future seismic monitoring in the rift area.

In the initial planning stages of this major seismic experiment, there were many concerns about logistics and technical matters that made a preliminary experiment highly desirable. After a few years of preparations, this was finally carried out in 1985. Its design, achievements and preliminary results on crustal and upper-mantle structure, taken together with experience gathered in earlier investigations, have been summarized by Swain et al. (1994-this volume). The 1985 experiment which included a 600-km-long E–W profile of teleseismic observations (Dahlheim et al., 1989; Achauer, 1990, 1992) made it clear that major scientific questions about the Kenya rift remained unanswered and that a major subsequent experiment was logistically feasible. Consequently, the KRISP Working Group organized a combined teleseismic and seismic-refraction/wide-angle reflection study of the Kenya rift in 1989 and 1990 which was able to obtain detailed information on the structure of the crust and uppermost mantle to depths of nearly 200 km.

The purpose of this paper is to describe the design and technical aspects of both the active refraction/wide-angle reflection portion and the passive teleseismic portion of the seismic study in 1989 and 1990 and thus serves as an introduction to the detailed descriptions of data and results which will be given in the subsequent contributions of this volume.

2. Lessons from KRISP 85

The 1985 KRISP seismic-refraction/wide-angle reflection effort (KRISP Working Group, 1987; Henry et al., 1990; Keller et al., 1991) as well as the teleseismic experiment (Dahlheim et al., 1989; Achauer, 1990, 1992; Green et al., 1991; Achauer et al., 1992; Green and Meyer, 1992) were preliminary experiments that grew somewhat beyond their original intentions and became experiments in their own right, as a result of the proposal review process. The refraction/wide-angle experiment was carried out during August 1985 and consisted of two profiles located within the rift valley. One was a short cross-line, and the other was a longer axial line which extended southward from Lake Baringo to the Lake Magadi area (KRISP Working Group, 1987; Henry et al., 1990, fig. 1). The teleseismic observations consisted also of two parts: a 600-km-long profile across Kenya at about 1°S (19 stations with an average spacing of 30 km) and a small array (100 × 100 km) centered in the rift valley in the vicinity of Mount Longonot volcano (Green and Meyer, 1992, fig. 1). Swain et al. (1994-this volume) summarize and discuss the scientific results of this earlier experiment, but its primary purpose was to provide the experience and information necessary to ensure the success of a major experiment.

The most significant technical result of KRISP 85 was the realization that the lakes were invaluable as shotpoints. Drilling was very expensive, and good seismic coupling of explosions in drillholes was a problem because the region was more arid than generally believed. Jacob et al. (1994-this volume) discuss the seismic source characteristics in detail. As a result of the 1985 experience, a major consideration in the design of the main experiment was locating recording profiles so as to take advantage of the rift valley lakes and Lake Victoria as shotpoints. The process of gaining permission to use the lakes extensively for shooting ultimately delayed the main experiment by one year. However, the scientific gain was easily worth the wait, and the additional planning time certainly improved the experiment.

There were many other benefits from the preliminary experiment. Firstly, we learned how to work with the local authorities and people. Even the remote areas are populated to the extent that most of the field instruments were discovered by local people. Thus, it was important to inform local chiefs and government officials of our activities well in advance so that the instruments would not be disturbed. By taking this step, we had very few problems in this regard. Other lessons learned included how to work in the lakes with explosives, that vehicle reliability was a potential problem, that too much camping was a drain on personnel and equipment, that times of low seismic noise were different from that expected, and that safety considerations dictated that movements at night be held to a minimum.

Communication among our own field groups was a problem during the seismic-refraction experiment in 1985. The radio system used was inadequate, and the presence of a radio in a field camp implied the expectation of communication in spite of a schedule of operations and instructions to proceed unless a member of the headquarters team arrived with a new schedule. No radio would have been better than one which worked only partially. Since good communications were important, a major effort in the main experiment was the design and testing of a reliable radio system. This system required the full-time effort of two people, an extra trip to Kenya for testing, and the purchase of some radios.

In the case of the teleseismic long-range observations it was learned that the most accurate timing was provided by the Omega navigational system, as GPS was not yet available at that time. Also it became evident that preprocessing of the data recorded by the field stations would have to be done continuously during the main project in a headquarters established permanently at a central location and equipped with a capable field computer system.

In 1985, thirteen shots totalling seven tonnes

Table 1
KRISP 85 shot table

Shot	Size (tonnes)	Range (km)	Direction
Baringo 1	1.0	280	South
Chepkererat	0.3	80	South
Solai	0.4	60	South
Elementaita	0.4	15	North
Naivasha	0.7	140	North
Suswa 2	0.4	60	North
Magadi	1.0	140	North
Ewaso Ngiro	0.5	60	East
Ntulelei	0.2	40	East
Suswa 1	0.1	30	East
Margaret	0.2	20	West
Makuyu	1.1	50	West
Baringo 2	0.7	170	South

were fired (Table 1 and Henry et al., 1990, fig. 1): nine in holes drilled for this purpose and four in shallow lakes (one in Crater Lake near Lake Naivasha, one in the very shallow Lake Solai, halfway between Menengai and Lake Bogoria, and two in Lake Baringo). Signals were recorded from these shots at the distance ranges shown in Table 1. Though shots of similar size gave excellent signals up to distances of at least 150 km in western Europe, e.g. in the Rhinegraben area (Jentsch et al., 1982; Gajewski and Prodehl, 1987), in the Kenya rift only in the case of a few shots did the energy reach distance ranges which were suitable to investigate the whole crust.

At the time, a large set of matched digital or analogue instruments was not available and thus the experiment involved a variety of 3-component stations as follows:

U.K.—17. This set of analogue instruments consisted of six GEOSTORES all with central base stations and all but one with two telemetering outstations.

U.S.—14 digital recorders from the University of Wisconsin made to their own design.

U.S.—10 digital DR100 recorders from Texas A and M University, the University of Texas at El Paso, and the U.S. Geological Survey.

Germany—10 standard MARS analogue recorders, model 1966.

Switzerland—3 standard MARS analogue recorders, model 1972.

Seismometers, amplifiers, etc. also varied within these groups of instruments. This mixing of instrumentation caused many problems in preparing the final data set. So a major consideration in the 1990 effort was to keep the instrumentation as standard as possible.

A P-wave record section of the data for the two 1985 shots at Lake Baringo recorded to the south is shown in Fig. 2. The seismograms shown have been band-pass filtered from 1 to 20 Hz, and trace-normalized. The correlation of phases is that from KRISP Working Group (1987).

The teleseismic tomography experiment of 1985 used the same types of recording equipment and seismometers as that of 1989/1990, and the experience of their performance during both a dry and a wet season in the field in 1985 was extremely important for the success of the main campaign in 1989/1990.

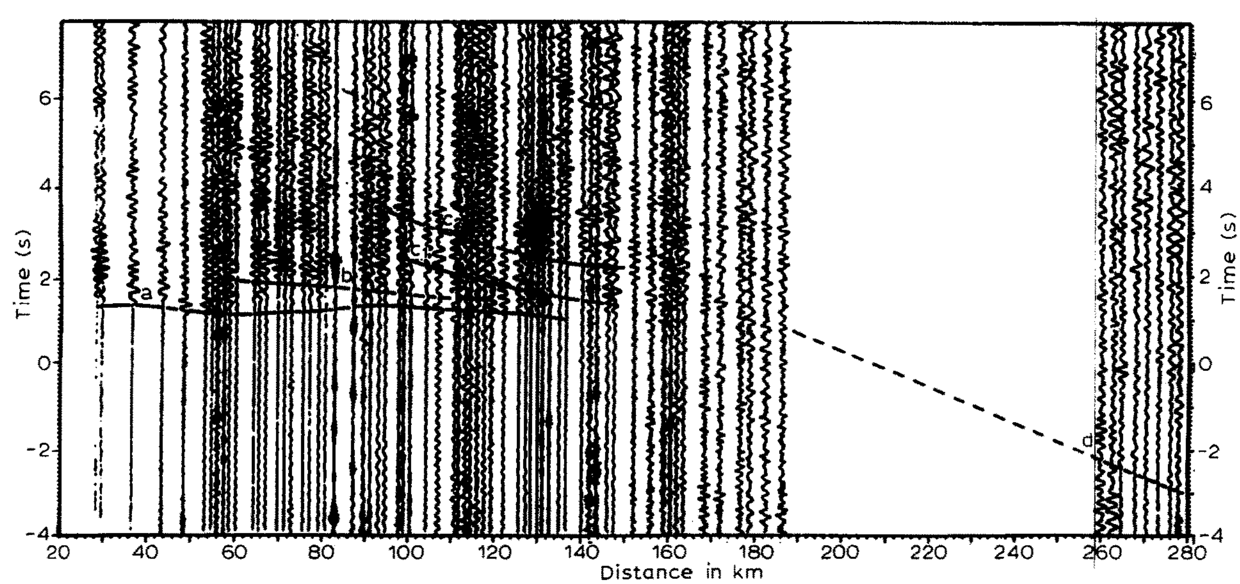

Fig. 2. Record section of BAR85-south (correlations from KRISP Working Group, 1987).

Table 2

KRISP 90 organization—Kenya Rift International Seismic Project, a project of the International Lithosphere Program (ILP) and the National Committee for Geodesy and Geophysics, Kenya

KRISP-coordinators

Local:	Prof. Dr. I.O. Nyambok, Department of Geology, University of Nairobi, P.O. Box 30197, Nairobi, Representative, Ministry of Energy, Nairobi
International:	C. Prodehl, Geophysical Institute, University, Hertzstr.16, D-76187 Karlsruhe

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Egerton University
Moi University, Nairobi
Department of Mines and Geology
Ministry of Energy (Kenya Power and Lighting Company)
Department of Fisheries
National Environment Secretariat
National Council for Science and Technology
Survey of Kenya
Ministry of Water Development
Kenyatta University, Department of Geography
Kenya Marine and Fisheries Research Institute
Kerio Valley Development Authority
Lake Basin Development Authority

(2) *The European Community*:
Denmark, University of Copenhagen
F.R. Germany, University of Karlsruhe
France, University of Paris
Ireland, Dublin Institute for Advanced Studies
Italy, Institute of Applied Geophysics, CNR, Milano
United Kingdom, University of Leicester

(3) *United States of America*:
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Purdue University, West Lafayette, Indiana
Stanford University, Stanford, California
University of Texas, El Paso, Texas
University of Wisconsin, Madison, Wisconsin
U.S. Geological Survey, Menlo Park, California
Texas A and M University, College Station, Texas

(4) *Australia*:
Australian National University

International Information Contact

UNESCO Regional Office for Science and Technology, Nairobi

Local coordinating committee for KRISP in Kenya

Prof. I.O. Nyambok, Chairman
Mr. J.D. Obel, Alternate Chairman
Dr. S.J. Gaciri, University of Nairobi, Geology Department
Prof. J.P. Patel, University of Nairobi, Physics Department
Prof. R.S. Rostom, University of Nairobi, Surveying Department

Table 2 (continued)

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Prof. M. Tole, Moi University	
Prof. J.M. Ndombi, Egerton University, Physics Department	
Mr. H.T. Macharia, Mines and Geology Department	
Mr. J.G. Mukinya, Department of Fisheries	
Mr. W.S. Okoth, Ministry of Energy	
Mr. Nzioka, Kenya Marine and Fisheries Res. Inst.	
Mr. Kinyanjui, National Environment Secretariat	
Mr. J.O.P. Nyagua, National Council of Science and Technology	
Mr. J.K. Ndede, Survey of Kenya	
Mr. F.K. Mwango, Ministry of Water Development	
Mr. J. Karanja, Lake Basin Development Authority (LBDA)	
Mr. M. Lilako, Kerio Valley Development Authority (KVDA)	
Mr. S.B. Ojiambo, Kenya Power and Lighting Company (KPLC)	
KRISP-management	
Scientific advisors:	
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Project management:	C. Prodehl (Karlsruhe)
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Organizing committee:	G.R. Keller (El Paso), M.A. Khan (Leicester), W.D. Mooney (Menlo Park), C. Prodehl and J. Mechie (Karlsruhe), L.W. Braile (Purdue); J.Barongo (Nairobi), J.S. Ogola (Nairobi), J.P. Patel (Nairobi), H.T. Macharia (Geology and Mines), J.G. Mukinya (Fisheries), M. Mwangi (KPLC), F. Mwango (Water)
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Project management:	P. Davis (Los Angeles)
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C. Geologic investigations:	
Project management:	M. Strecker (Karlsruhe)
Local organisor:	S.J. Gaciri (Univ. of Nairobi)
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3. Logistics and pre-site surveys for the KRISP 90 experiment

3.1. Coordination

The programme involved numerous countries and institutions and was only possible due to the excellent international cooperation of the individual participating scientists. This cooperation could only be handled by a careful division of tasks. Table 2 lists institutions and provides an overview of the management.

To deal with a variety of local problems, a Kenyan KRISP Local Coordinating Committee was created where all groups interested in this unique experiment were represented (Table 2). It included scientists of the Kenyan universities as well as representatives of government agencies. Its tasks were to deal with permits, visits to local government representatives, informing the public, duty-free import of instruments and explosives, and to provide KRISP with Kenyan scientists, students, and technicians to join the field parties.

3.2. Communication

To ensure communication during the whole seismic-refraction operation, a reliable radio network had to be established. It consisted of three parts. Firstly, for general communication between headquarters and field parties (5 shotpoints and 2 observer camps), short-wave radios (frequencies 3165.5 and 7978.5 kHz) were permissioned. Two radio stations were permanently installed at Nairobi and at the game lodge of Maralal in central Kenya and were, during the time of the seismic-refraction field work, continuously operated for 24 hours. This system also served to control the master clocks of the seven mobile units at shotpoints and observers' field camps. The setting of the master clocks was daily synchronized with a time signal provided by the Maralal subheadquarters and controlled there regularly by comparing it with universal time broadcasted by the Moscow short-wave radio station.

Secondly, each mobile group (shotpoint and observer crews) was equipped with a car radio operating on a citizen band frequency (27022 kHz) to deal with emergency cases and car-to-car communication over some tens of kilometers. Thirdly, hand-held radios served for short-distance communication (some hundred meters) at shotpoint sites (e.g., lake center to shore). To ensure a safe operation, the short-wave transmission conditions were tested in a reconnaissance field trip in September 1989.

3.3. Shooting

As a consequence of KRISP 85, lakes were used as shotpoints as much as possible. The technique employed, which was to subdivide charges into smaller, separated, units made the underwater explosions even more efficient and had less effect on the lake bottom. The shallower the water depth, the smaller is the optimum size of the individual charge. Charges suspended some meters above the lake bottom and some meters beneath the fish populated surface layer of the lake were used wherever the total water depth permitted it. Deeper water also permitted shots at optimum depth where the surface reflections reinforce the seismic signal produced by the bubble pulse. Such techniques had been first tested by Jacob (1975) and applied to long-distance observations to nearly 1000 km during LISPB in 1974 (Bamford et al., 1976).

To test this shooting technique and its effects quantitatively and to assess its practical aspects in lakes, special test experiments were designed and carried out both in Ireland and in Kenya well before the main experiment (Jacob et al., 1994-this volume). As a consequence, the layout and size of underwater shots during the main experiment could be considerably improved and thus allowed a considerable reduction of the largest charges from 5 tonnes to 1–2 tonnes. Details of the shooting operation and an evaluation of its main aspects are discussed by Jacob et al. (1994-this volume).

Following good experience with river shots in Ethiopia (Burkhardt and Vees, 1975), test shots were also performed in the Ewaso Ngiro River, where two shotpoints had been planned at sites near the town of Barsalinga (BAS) and at Chanler's Falls (CHF), 50 km east of Archers Post. It was hoped that here expensive and risky drilling of boreholes could be avoided. Unfortunately, the test shot series carried out in September 1989 did not prove to be successful and therefore at these two positions borehole shots had to be used.

3.4. Environment

The 1985 KRISP experiment provided the opportunity to study potential effects on the environment by underwater explosions in Lake Baringo. From the beginning of KRISP 85, close contact was maintained with the Fisheries and Wildlife Kenya government departments which sent observers. The 1-tonne shots killed an insignificant amount of fish and, in spite of strong blow-outs, the wave reaching the shore was only about 20 cm high. The experience with underwater explosions during KRISP 85 together with former worldwide experience (E. Criley, oral commun., 1989; Jacob et al., 1994-this volume) permitted an assessment of damage expected during the 1990 experiment. Since the total amount of charge for individual shots was about the same size as in 1985 and their effect could be reduced by modern shooting techniques of subdivided and dispersed charges, it was not to be expected that the effects of underwater explosions on lake bottoms and aquatic life would exceed those of the 1985 experiment. Representatives of the Fisheries Department accompanied the project from the planning to the final selection of the shot sites and observed the effects on aquatic life of the experiment after a variety of KRISP 90 shots.

3.5. Pre-site survey

Not only the shotpoints, but also all recording sites of the refraction survey were located well before the experiment in a two-months expedition in August and September 1989. Sites were marked, local people addressed, and coordinates determined by GPS measurements with an accuracy of ± 15 m (table 2 in KRISP Working Group, 1991). Thus, the access to all points was assured and enabled the observers during the main experiment, in spite of partly insufficient maps, to reach each of their recording sites of each deployment quickly and safely.

For the teleseismic experiment most of the recording sites were located in two pre-experiment site surveys in 1988 and 1989 and permits were obtained where necessary. Some sites were located during the installation phase and in a few cases it proved necessary to move instruments to another site due to security problems or unforeseen "noise" sources, mainly if local people lived nearby.

4. Design of the main refraction experiment

The seismic programme for 1989–90 involved a teleseismic observation phase with about 65 earthquake recording stations which were temporarily installed at fixed sites for 6–7 months within an area of about 300 km × 200 km (trapezoidal area in Fig. 1), as well as three seismic-refraction/wide-angle reflection profiles in January/February 1990 (lines in Fig. 1). This effort involved the recording of underwater and drillhole explosions along the rift valley and on its flanks by 206 mobile seismographs along these three profiles and by all teleseismic recording stations (trapezoidal area in Fig. 1): (a) lines A, B, C between Lake Turkana and Lake Magadi; (b) line D between Lake Victoria and Chanler's Falls (CHF); (c) line E between Lake Turkana and Chanler's Falls (CHF); (d) central rift and neighbouring flanks (trapezoidal area).

The positions of the profiles had to meet a series of requirements. As discussed above, the shotpoints in the rift were positioned in lakes wherever possible. Where lakes were not available, borehole shots were planned. In this case, low areas with a shallow groundwater table were sought so that the charges could be hopefully detonated below the water table. Not less important were security precautions. Furthermore the shotpoints had to be accessible by road and/or by boat. In particular, accessibility of the area by roads dictated the final positions of shotpoints and recording stations.

The purpose of the main line which followed the axis of the rift (Fig. 1) was to obtain a detailed crustal model of the rift proper and to obtain structural information as deep as possible on the uppermost mantle. Along this profile, all shotpoints but one could be placed in lakes: Lake Turkana, Lake Baringo, Lake Bogoria, and Lake Naivasha. Half way between Lake Turkana and Lake Baringo a borehole shot was foreseen which, however, did not prove to be very successful. Due to uncertainty in the shot efficiency and financial constraints, a shotpoint at the southernmost end of the Kenya rift, in the vicinity of Lake Magadi, could not be realized.

The main rift profile was 550 km long and was recorded in three deployments.

Deployment A: recording along Lake Turkana at 206 points at a station interval of 0.7 km; firing small shots of 100–400 kg, two each at positions 350 m apart at LT1, LT3, and LT5 aiming for an apparent observation interval of 350 m for these shots; and one each at positions LT2 and LT4 (for more details see Gajewski et al., 1994-this volume).

Deployment B: recording at 206 points at 1.5 km intervals between Lake Turkana and Lake Baringo with underwater shots at LTN and LTC in Lake Turkana, Lake Baringo (BAR), Lake Bogoria (BOG) and Lake Naivasha (NAI) and one borehole shot near Lokori (LKO) (for more details see Mechie et al., 1994b-this volume, and Keller et al., 1994a-this volume).

Deployment C: recording between Lake Baringo and Lake Magadi with a similar arrangement of stations and the same positions for underwater shots as deployment B (for more details see Mechie et al., 1994b-this volume, and Keller et al., 1994a-this volume). To increase station density, during this deployment one additional shot in Lake Bogoria (BOG) was fired.

The cross-profile (deployment D) was 450 km long, extending from Chanler's Falls (CHF) through Lake Baringo (BAR) to Lake Victoria (VIC). This profile which was perpendicular to the strike of the rift, was carried out to obtain crustal models for both the western and eastern flanks of the rift, as well as to get some additional insight into the rift proper including the transition from the rift to the flanks. It was positioned so that underwater shots in Lake Victoria (VIC) in the west and in Lake Baringo (BAR) in the center could be used. To the east the line extended as far as Chanler's Falls (CHF) on the Ewaso Ngiro River where security reasons prohibited a shotpoint for this deployment. In addition, several borehole shots were located near the towns of Barsalinga (BAS), Tangulbei (TAN) and Kaptagat (KAP). These were located at positions with a shallow groundwater table and all proved to be successful with good energy propagation. About 40 additional stations along this line were provided by temporary earthquake networks of Leicester University and the IPG Paris. Thus, in the rift proper, the station interval was as small as 1 km. Across both flanks the station spacing was 2 km to about 120 km east and 170 km west of Lake Baringo, respectively, and 5 km at both ends of the line (for more details see Maguire et al., 1994-this volume, and Braile et al., 1994-this volume). Aiming for some high-resolution data during deployment D, four shots at 250 m intervals in an E–W direction in Lake Baringo were fired.

The last profile (deployment E) was positioned on the eastern flank of the rift (Fig. 1). The purpose was to obtain a model for an area which was not influenced by the processes shaping the Kenya rift. For logistical reasons, however, the proximity of the nearby Mesozoic Anza rift (Bosworth, 1992; Morley et al., 1992; Morley, 1994-this volume; Dindi, 1994-this volume) could not be avoided, as the line was arranged so that Lake Turkana could be used as a shotpoint at the northwestern end, while along the rest of the line only drillhole shots could be planned. This east flank profile (deployment E) was 300 km long and ran in a NW–SE direction from Lake Turkana to Chanler's Falls (CHF) on the Ewaso Ngiro River, 50 km east of Archers Post. The 206 stations recorded underwater shots at two positions in Lake Turkana (LTS and LTC) and borehole shots near Illaut (ILA), Laisamis (LAI) and Chanler's Falls (CHF). The station spacing was 1.5 km, with a 10-km gap 50 km SE of Laisamis because of a lack of roads and no observations between the two Turkana shots LTS and LTC (for more details see Prodehl et al., 1994-this volume).

5. Methodology of the refraction project

5.1. General

In total 72 scientists, technicians and students were involved in the field work and were subdivided into recording, technical services, headquarters, and shooting parties (Table 3). For each group, a special logsheet was created regulating the individual movements (Fig. 3). Each of the fourteen recording groups (two people, one 4-wheel-drive vehicle each) handled, with one exception, fifteen recording stations. The observer groups were equipped with light camping equipment sufficient to survive 3–4 nights in field camps comprised of 5–6 parties. Between the individual deployments, all groups passed through a mobile headquarters where batteries were recharged, equipment repaired and tapes col-

Table 3
Field units of the KRISP 90 refraction project

1.1. *Recorders (Rc1–Rc14)*		
Rc1	Jim Luetgert (USGS), Duncan Kaburu (NBO)	2 [a]
Rc2	Don Roberts (UTEP), Ken Olsen (Los Al.)	2
Rc3	Uwe Kästner (KA), Nelson Kiruki (NBO)	2
Rc4	Werner Kaminski (KA), Martina Demartin (MI)	2
Rc5	Mark Baker (UTEP), Alex Githui (UTEP)	2
Rc6	Stephen Hughes (LEI), Jim Mechie (KA)	2
Rc7	Tom Blake (DIAS), David Mutai (NBO)	2
Rc8	Peter Readman (DIAS), Clare Horan (DIAS)	2
Rc9	Steve Harder (TEXAS A and M), Douglas Abuuru (NBO)	2
Rc10	Brennan O'Neill (USGS), Bonnie Rippere (STA)	2
Rc11	Klaus Jöhnk (KA), Rolf Stellrecht (KA)	2
Rc12	Beate Aichroth (KA), Uwe Enderle (KA)	2
Rc13	Raimund Stangl (KA), Hans Thybo / Frans Schjödt (COP)	2
Rc14	Mark Goldman (USGS), Wayne Kirk (LEI)	2
1.2. *Equipment and communication (Tc1 and Tc2)*		
Tc1	Heinz Hoffmann (KA), Fred Fischer (USGS)	2
Tc2	Ron Kaderabek (USGS), Matthias Schoch (KA)	2
1.3. *Computer Centre (Cp)*		
Cp1	Tom Parsons (STAN), Bill Lutter (PURD)	2
1.4. *HQ / Service (HQ)*		
HQ1a	Claus Prodehl (KA) and Don Riaroh (NBO)	2
HQ1b	J.P. Patel (NBO) and Steven Gaciri / Isaac Nyambok (NBO)	2
HQ2	Aftab Khan (LEI) and N. Kamundia (NBO)	2
HQ3	Randy Keller (UTEP) and E. Imana / J. Ndombi (EGE)	2
HQ4	Don Griffiths (LEI) and C. Wafula (NBO)	2
HQ5	John Mukinya (NBO)	1
1.5. *HQ / Communication (Cm)*		
Cm1	Jürgen Oberbeck (KA), Paul Coward (LEI)	2
1.6. *Shooters (ShB, ShD, ShE, ShL, ShR, U1, U2 / 3)*		
ShB	Brian Jacob (DIAS), Gerry Wallace (DIAS), Alan Musset (LIV), Brian O'Reilly (DIAS) for BAR1–BAR4, BAx1–BAx4, ILA	4
ShD	Dirk Gajewski (CLZ), Christian Große (KA), Andreas Schulte (CLZ), J.K.Ndede (NBO) for LT5, LTC1, LTC2, VIC, LTC3	4
ShE	Ed Criley (USGS), Jarl Jepsen (COP), Joseph Cotton (USGS), T.Kimani (NBO) for LT2, BOG1, BOG2/3, BAS, LAI	4
ShL	Larry Braile (PURD), Roger Bowman (ANU), J.P.G. Mburu (NBO) for LT3, NAI1, NAI2, KAPS, CHF	3
ShR	Roland Vees (CLZ), Joachim Geppert (CLZ), Tom Elvers (CLZ), Edwin Dindi (NBO / CLZ) for LT4, LTN1, LTN2, TAN, LTS	4
U1	Walter Mooney (USGS), Julius Mwabora / K.Kairu (NBO)	
U2/3	Mariano Maistrello (MI), Andreas Rüger (KA) for LT1, LKO, (BOG3), (BAx)	4
1.7. *Servicing*		
Serv1	Doris Zola (Nairobi)	
Serv2	Pravin Bowry (Nakuru)	
Serv3	S. Kanyi and helper (Inside Africa Safari)	2
		72

[a] Number of persons.

```
                      KRISP 90 LOGSHEET 4: movement of Observers
                                        1
                          Scheme of recorders' distribution

1 to 14: recording teams
*       shotpoint
O       field camp

           1  | 3       5  | 7       11        |  | 11  13
    - - - - - | - - - - - -| - - - - - - -13   |  | - - - - -
                                                          -
*             |     o      |     o        __*  |  | or      *
    - - - - - | - - - - - -| - - - - - - - -   |  | - - - - -
                                                          -
           2  | 4       6  | 8       10        |  | 12  14

          Distribution of Recorders (Rc) for individual deployments
Deployment A: from N to S  : 1,6; 3,12,4,9; 7,8,10,13;14;2,5,11.
Deployment B: from N to S  : 1,11; 3,4,6; 5,12; 2,7,8,9; 10,13,14.
Deployment C: from N to S  : 14,1,4,11; 2,3,12,7,10,8,9; 6; 5,13.
Deployment D: from E to W  : 1,10; 3,8,7,13; 14; 5,6,12; 11,2,4,9.
Deployment E: from NW to SE: 1,10; 2,3,4,9; 8,11,6,7; 5,12,13,14.
Jan/Feb Day
90       no.
---------------------------------------------------------------------
18 Thu   0        -------------------arrive at NBO-----------------
19 Fri   1    overtake vehicles and equipment, check for completeness
20 Sat   2        ---------drive NBO - NAK - KIT (165 + 235 km)------
21 Sun   3        ------drive KIT-LODWAR (315 km)- TUR (70 km)------
22 Mon   4        -----check equipment, huddle test 15:00 (10 km)---

            --------------------------------------------------------------------
                  Rc1,6       Rc3,12      Rc7,8       Rc14        Rc2,5,11
      A           (1-30)N     (31-60)N    (91-120)N   (151-161)   (162-206)S
                              Rc4,9       Rc10,13
                              (61-90)S    (121-150)N
            --------------------------------------------------------------------
23 Tue   5        ------check equipment,  program     laptops for A-------------
                  to LT1/2    to camp1    at TUR      at TUR      at TUR
                              near LT3
                  (ShU/E)     (ShL,Tc1)   (Tc2)       (Tc2)       (Tc2)
                  110km       80km        0km         0km         0km
24 Wed   6        2 Lapt      3 Lapt      ----------5 Lapt----------------------
                  ---------------program stations for A-------------------------
                  ==================deployment A================================
                  30km        35km        70km        70km        70-90km
                              35km        40km
     night at     Todenyang   LT1/2       st.90       TUR         LT5
                              st.90       LT4                     (or st.206)
     17.30-17.50================== shots A =================================
     18.30-18.36              shots A reserve
25 Thu   7   12.45            shots A reserve
                  ----------------------pick up---------------------------------
                  (30)LT1/2   (35)camp1   (70)TUR     (40)TUR     (70-90)TUR
                              (35)camp1   (40)TUR
                    EOF       EOF         EOF         EOF         EOF
                  (110)TUR    (80)TUR
                              (80)TUR
```

Fig. 3. Section of logsheet 4: movement of observers.

KRISP 90 LOGSHEET 4: movement of Observers 2

```
Jan/
Feb     Day
90      no.
             -----------------------------------------------------------------
                Rc1,11       Rc3,4,6      Rc5,12       Rc2,7        Rc10,13
     B          (-3-24)      (28-75)      (76-105)N    (106-135)N   (166-195)
                                                       Rc8,9        Rc14
                                                       (136-165)S   (196-206)
             -----------------------------------------------------------------
26 Fri   8      -----------repair, program laptops for B-------------------
27 Sat   9      to LTC       to camp1     to LKO       to camp2     to BAR
                (ShD)        at Kerio     (ShE)        (Tc2)        (ShB)
                (70)LODW     (Tc1)        (70)LODW     (70)LODW     (70)LODW
                (60)LTC      (70)LODW     (165)LKO     (165)LKO     (315)KIT
                             (60)Kerio                 (60)»S       (70)ELD
                                                                    (85)KAB
______________________________________________________________________________
28 Sun 10                                                           (70)BAR

                2 Lapt       2 Lapt       2 Lapt       2 Lapt       2 Lapt
                at LTC       move         at LKO       at camp2     at BAR
                --------------program stations for B-----------------------
                =================deployment B===============================
                100km        125km        75km         60km         80km
                                                       60km         40km
     night at   LTC          st.75        st.76        N:LKO        KAP
                (or st.24)                             S:KAP        BAR
                17.30-17.40========= shots B ==============================
                18.15-18.17 reserve shots B
______________________________________________________________________________
29 Mon 11    or 12.45-12.55========= shots B ==============================
                13.45-13.47 reserve shots B
                --------------start to pick up-----------------------------
______________________________________________________________________________
30 Tue 12            -------------continue to pick up----------------------
                100km        125km        75km         60km         80km
                                                       60km         40km
                 EOF          EOF          EOF          EOF          EOF
                at LTC       at Kerio     at LKO       at camp2     at BAR
                (60)LODW     (60)LODW     (185)BAR     (155)BAR
                (315)KIT     (315)KIT                  (155)BAR
______________________________________________________________________________
31 Wed 13       (70)ELD      (70)ELD
                (155)BAR     (155)BAR
                -------charge, repair, program laptops for C---------------
______________________________________________________________________________
 1 Thu 14       --------------------spare day------------------------------
______________________________________________________________________________

             -----------------------------------------------------------------
                Rc14         Rc2,3,12                Rc6          Rc5,13
                (1-11)       (57-101)N               (162-176)    (177-206)S
     C          Rc1,4,11     Rc7,10
                (12-56)      (102-131)S
                             Rc8,9
                             (132-161)S
             -----------------------------------------------------------------
 2 Fri 15       at BAR       to NAK                  to NBO       to NBO
                (lodge)      (hotel)                 (hotel)      (hotel)
                (ShB)        (Tc1)                                (Tc2)
                0km          (120)NAK                (120)NAK     (120)NAK
                                                     (165)NBO     (165)NBO
```

Fig. 3 (continued).

lected. After each deployment, the tapes from the SGR equipment (see below) were transported to the temporary data processing center at Egerton University near Nakuru and partly processed.

Five self-sustaining shooting parties (four people and two 4-wheel-drive vehicles each) were responsible for efficient and safe shooting following a tight schedule (Table 4). They were serviced by four trucks carrying explosives and other gear, whose accompanying headquarters personnel had to follow a very flexible schedule to make sure that the explosives arrived at the individual shotpoint well in advance but not before the shooting crews arrived from the previous shotpoint. Occasionally some of the trucks had to deliver food and petrol, which was not allowed to be transported together with explosives, to remote camps

Table 4
KRISP 90 explosion field work schedule for observers

Jan/Feb	Day nr.	
4–17		Preparations of advance group
18 Thu	0	Arrival
19 Fri	1	Organize in Nairobi
20 Sat	2	Leave Nairobi for field
21 Sun	3	Arrive at Lake Turkana Lodge
22 Mon	4	Organize, program instruments, huddle test 3 p.m.
23 Tue	5	Check instruments. Move to recording areas
24 Wed	6	Deploy on A, record shots LT1–LT5 at 4 p.m.
25 Thu	7	Pickup and go to Lake Turkana Lodge
26 Fri	8	Playback, repair instruments, charge
27 Sat	9	Drive to camp on deployment B—axial line N
28 Sun	10	Deploy on B, shots at 5.30 p.m.
29 Mon	11	Pick up deployment B
30 Tue	12	Continue to pick up and drive to Baringo Lodge
31 Wed	13	Playback, repair, charge
1 Thu	14	Spare day, tapes to Egerton
2 Fri	15	Drive to camps for deployment C—axial line S
3 Sat	16	Deploy on C, shots at LTC and LTN at 7.30 p.m.
4 Sun	17	Shots at 6.30 a.m., pickup, and drive to Baringo Lodge
5 Mon	18	Playback, repair, charge
6 Tue	19	Spare day, tapes to Egerton
7 Wed	20	Travel to camps on D—cross-line
8 Thu	21	Deploy on D
9 Fri	22	Shots at 2 a.m., pick up and drive to Maralal lodge (MAR)
10 Sat	23	Playback, repair, charge. Tapes to Egerton
11 Sun	24	Playback, repair, charge
12 Mon	25	Travel to camps on E-flank line
13 Tue	26	Deploy on E, shots at 5 p.m. except LTS
14 Wed	27	Re-program stations on line E for LTS
15 Thu	28	Shot LTS at noon, pickup and return to MAR and BUF
16 Fri	29	Return to Nairobi, reception of KRISP at German Embassy
17 Sat	30	Complete paper-work, demobilize, KRISP farewell party
18 Sun	31	Demobilize, final meeting, pack instruments
19 Mon	32	Departure of majority (1 and 5 a.m.), clean up
20 Tue	33	Clean up
21 Wed	34	Clean up, equipment to airport
22 Thu	35	Clean up, return of rented equipment, last rental cars
23 Fri	36	Spare day for discussions on future projects
24 Sat	37	Spare day
25 Sun	38	Departure of last group (1 a.m.)

in northern Kenya. A specially assigned repair crew accompanied the project to take care of vehicle breakdowns and punctures on the rough roads and countryside.

5.2. Shooting

In total 34 shots were fired from nineteen shotpoints with charges ranging from 100 to 2000 kg (Table 5). All lake shots resulted in good to excellent recordings. While in the rift energy propagation was limited to a maximum distance range of 400 km (shots LTN and LTC), the Lake Victoria shot could be observed along the whole length of the cross-line out to 450 km. For the remaining shot sites, boreholes had to be drilled. Only the borehole shot at Lokori (LKO) which could not be fully loaded, was not efficient.

For all shots, not only were the major crustal phases such as P_g, P_iP and P_mP well recorded with suitable energy out to 200–250 km distance, but P_n arrivals can also be traced out to beyond 200 km distance. Table 5 shows the details of all the shots employed in 1990.

Table 5
KRISP 90 shotpoint coordinates and origin times (local times)

Shot	Origin time		Position		Height (m)	Charge size (kg)	Shot type
	date	time (h:min:s)	latitude	longitude			
LT11	24.01.90	16:00:08.75	4°18.77′N	35°56.17′E	390	400	Water
LT31	24.01.90	16:04:00.00	4°03.90′N	35°55.78′E	390	100	Water
LT41	24.01.90	16:06:00.18	3°45.01′N	35°51.43′E	390	100	Water
LT51	24.01.90	16:08:00.67	3°19.88′N	35°59.36′E	390	275	Water
BAR1	24.01.90	16:10:01.10	0°38.15′N	36°04.38′E	970	1200	Water
LT21	24.01.90	16:15:54.95	4°11.22′N	35°57.00′E	390	300	Water
LT32	24.01.90	16:18:00.00	4°03.71′N	35°55.78′E	390	100	Water
LT52	24.01.90	16:22:00.26	3°19.76′N	35°59.50′E	390	125	Water
LT12	24.01.90	16:24:00.57	4°18.58′N	35°56.17′E	390	100	Water
LTN1	28.01.90	17:30:00.36	3°43.86′N	35°56.26′E	360	800	Water
LTC1	28.01.90	17:33:00.09	3°17.53′N	36°03.18′E	360	800	Water
BAR2	28.01.90	17:36:14.99	0°38.15′N	36°04.38′E	970	1500	Water
BAG1	28.01.90	17:39:18.59	0°13.39′N	36°06.99′E	990	400	Water
NAI1	28.01.90	17:42:00.01	0°46.68′N	36°21.77′E	1890	2000	Water
LKO	28.01.90	17:45:00.00	2°00.06′N	35°59.28′E	635	125	Hole
LTN2	03.02.90	19:30:00.49	3°43.86′N	35°56.26′E	360	975	Water
LTC2	03.02.90	19:33:00.20	3°17.53′N	36°03.18′E	360	825	Water
NAI2	04.02.90	06:25:59.98	0°46.68′S	36°21.78′E	1890	750	Water
BOG2	04.02.90	06:32:00.83	0°13.68′N	36°06.99′E	990	300	Water
BAR3	04.02.90	06:50:04.44	0°38.15′N	36°04.38′E	970	800	Water
BOG3	04.02.90	06:53:00.85	0°13.39′N	36°06.99′E	990	300	Water
BAR4	09.02.90	02:00:05.66	0°38.15′N	36°04.38′E	970	500	Water
VIC	09.02.90	02:03:00.05	0°12.89′S	34°07.63′E	1110	1000	Water
KAP	09.02.90	02:06:00.00	0°20.52′N	35°24.02′E	2230	900	Hole
BAX1	09.02.90	02:09:03.23	0°38.14′N	36°04.26′E	970	300	Water
TAN	09.02.90	02:12:00.71	0°48.85′N	36°16.38′E	1160	800	Hole
BAX2	09.02.90	02:15:03.32	0°38.17′N	36°04.50′E	970	300	Water
BAS	09.02.90	02:17:59.90	0°47.28′N	37°05.97′E	1070	2000	Hole
BAX3	09.02.90	04:00:03.16	0°38.13′N	36°04.18′E	970	300	Water
LTC3	13.02.90	16:59:59.92	3°17.53′N	36°03.18′E	360	800	Water
ILA	13.02.90	17:06:00.60	1°52.11′N	37°15.28′E	730	900	Hole
LAI	13.02.90	17:08:59.95	1°33.40′N	37°49.59′E	570	900	Hole
CHF	13.02.90	17:12:00.00	0°48.39′N	38°00.75′E	675	2000	Hole
LTS	15.02.90	12:00:00.00	2°41.35′N	36°36.95′E	340	375	Water

5.3. Recording

A total of 206 portable recording stations were employed. Of these, 186 were one-component digital seismic group recorders (SGR III) which are jointly maintained by Stanford University, the U.S. Geological Survey, and the U.S. Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL). These instruments have been modified to include a quartz clock which serves as a timer and as a reference for programmed recording intervals. The clocks are set during programming by laptops, the internal times of which are controlled by a master clock. Table 6

K R I S P 89-90 RECORDING SITE COORDINATES

LAKE TURKANA H.-R. STUDY

SITE	LATITUDE	LONGITUDE	HEIGHT M	HEIGHT FT				MAP HEIGHT M	MAP HEIGHT FT
1	4 27.41N	35 55.66E	410	1340	KA GPS PT. NO.	501	FM1	0	0
1	4 27.41N	35 55.67E	372	1220	USGS GPS PT. NO.	51	3-D	0	0
2	4 27.07N	35 55.57E			INTERPOLATED PT. NO.	1			
3	4 26.71N	35 55.48E			INTERPOLATED PT. NO.	2			
4	4 26.37N	35 55.40E			INTERPOLATED PT. NO.	3			
5	4 26.03N	35 55.31E	365	1197	USGS GPS PT. NO.	52	3-D	0	0
6	4 25.68N	35 55.25E			INTERPOLATED PT. NO.	5			
7	4 25.32N	35 55.19E			INTERPOLATED PT. NO.	6			
8	4 25.01N	35 55.13E			INTERPOLATED PT. NO.	7			
9	4 24.64N	35 55.07E			INTERPOLATED PT. NO.	8			
10	4 24.24N	35 55.00E	425	1387	KA GPS PT. NO.	502	FM1	0	0
11	4 23.89N	35 54.91E			INTERPOLATED PT. NO.	10			
12	4 23.56N	35 54.83E			INTERPOLATED PT. NO.	11			
13	4 23.23N	35 54.74E			INTERPOLATED PT. NO.	12			
14	4 22.90N	35 54.66E			INTERPOLATED PT. NO.	13			
15	4 22.52N	35 54.57E	365	1197	USGS GPS PT. NO.	53	3-D	0	0
16	4 22.20N	35 54.51E			INTERPOLATED PT. NO.	15			
17	4 21.90N	35 54.45E			INTERPOLATED PT. NO.	16			
18	4 21.39N	35 54.35E			INTERPOLATED PT. NO.	17			
19	4 20.99N	35 54.28E			INTERPOLATED PT. NO.	18			
20	4 20.60N	35 54.21E	424	1377	KA GPS PT. NO.	503	FM1	0	0
21	4 20.21N	35 54.17E			INTERPOLATED PT. NO.	20			
22	4 19.86N	35 54.13E			INTERPOLATED PT. NO.	21			
23	4 19.42N	35 54.09E			INTERPOLATED PT. NO.	22			
24	4 19.03N	35 54.05E	410	1344	USGS GPS PT. NO.	55	3-D	0	0
25	4 18.58N	35 54.07E	425	1376	KA GPS PT. NO.	504	FM2	0	0
25	4 18.58N	35 54.07E	395	1295	USGS GPS PT. NO.	54	3-D	0	0
26	4 18.22N	35 54.03E			INTERPOLATED PT. NO.	24			
27	4 17.83N	35 54.00E			INTERPOLATED PT. NO.	25			
28	4 17.40N	35 53.95E			INTERPOLATED PT. NO.	26			
29	4 17.01N	35 53.92E	400	1311	USGS GPS PT. NO.	56	3-D	0	0
30	4 16.76N	35 53.65E	445	1460	KA GPS PT. NO.	505	FM?	0	0
30	4 16.76N	35 53.64E	399	1308	USGS GPS PT. NO.	57	2-D	0	0
31	4 16.45N	35 53.64E	395	1295	USGS GPS PT. NO.	58	3-D	0	0
32	4 16.15N	35 53.36E	393	1289	USGS GPS PT. NO.	59	3-D	0	0
33	4 15.71N	35 53.16E	404	1325	USGS GPS PT. NO.	60	3-D	0	0
34	4 15.40N	35 53.18E	399	1308	USGS GPS PT. NO.	61	3-D	0	0
35	4 15.01N	35 53.14E	405	1328	USGS GPS PT. NO.	62	3-D	0	0
36	4 14.70N	35 53.30E	0	0	USGS GPS PT. NO.	63	2-D	0	0
37	4 14.40N	35 53.62E	394	1292	USGS GPS PT. NO.	64	3-D	0	0
38	4 14.22N	35 54.02E			INTERPOLATED PT. NO.	28			
39	4 14.06N	35 54.38E	370	1213	USGS GPS PT. NO.	65	3-D	0	0
40	4 13.76N	35 54.62E	438	1442	KA GPS PT. NO.	507	FM1	0	0
41	4 13.37N	35 54.53E			INTERPOLATED PT. NO.	30			
42	4 13.05N	35 54.45E			INTERPOLATED PT. NO.	31			
43	4 12.63N	35 54.35E	372	1220	USGS GPS PT. NO.	66	3-D	0	0
44	4 12.21N	35 54.31E			INTERPOLATED PT. NO.	33			
45	4 11.79N	35 54.27E	387	1269	USGS GPS PT. NO.	67	3-D	0	0

Fig. 4. Section of KRISP 90 recording site coordinates (from KRISP Working Group, 1991, table 2).

gives the technical details of the whole system. In addition, 20 programmable analogue tape recording units, also one-component stations, were supplied by the Dublin Institute for Advanced Studies (DIAS). All stations were equipped with 2 Hz-geophones, the vast majority of which were Mark II-L4 vertical seismometers.

In each of the five deployments, the stations were set out at the positions marked during the pre-site survey and for which the coordinates had been determined by GPS measurements as described above. In only a few cases, new sites had to be occupied. Fig. 4 shows the first page of the tabulation of station locations which can be found in KRISP Working Group (1991). In total, 1063 recording sites were occupied.

6. KRISP 90 tomography experiment (teleseismic survey)

Based on the experiences of the 1985 field experiment and extensive discussions with all groups involved, the recording area of KRISP 90 was placed just to the north of the 1985 area though the arrays overlap to some extent (Fig. 5). The network, centered around Nakuru (location of headquarters), had an oval outline with the long axis in the E–W direction and parallel to the 600-km-long E–W line of 1985 (Fig. 5). The interval distance between stations increased linearly with increasing distance from the array center. With only 60–70 stations available, it was thus possible to achieve both a rather dense network within the rift valley proper (average station spacing 10–15 km) and an extended array large enough to allow for a deep penetration into the upper mantle down to depths of about 150–200 km. Details of the array are given in Table 7.

As in 1985, a variety of instruments had to be used during the 1989–90 recording phase (Table 8). With the exception of the Geostores which record continuously, all seismic stations were independently operated in an event trigger mode, i.e. recording data only when the built-in microprocessor recognized an earthquake. All stations used a STA/LTA event detection algorithm adapted for recording teleseismic events.

All teleseismic stations were equipped with an Omega system for accurate timing ($dt < 10$ ms). Some of the stations (DL1 and Reftek) used a

Table 6
Technical specifications of the Stanford/USGS seismic-refraction equipment

Model:	SGR-III (Seismometer Group Recorder)
Description:	stand-alone, self-triggered, digital seismic recording system; triggering times are programmable; data are recorded on cassette tape
Manufacturer:	Globe Universal Sciences, Inc. (a division of Grant-Norpac, Inc.)
Availability:	the Stanford/USGS SGRs are available for use by all government and academic institutions
Number of units:	196
Sample rate:	0.002 s (cannot be changed)
Maximum recording time:	99 s; warm up time is of the order of 1 to 2 s
Low-cut filter options:	out or 8 Hz
Notch-filter options:	60 Hz in or out
Pre-amp settings:	400, 200, 100, or 50 mV, full-scale
Programmability:	99 shots can be programmed; however, there is not enough battery power to pull 99 shot records worth of tape.
Clock drift:	± 1 part in 10^7 from 0 to 50°C, ± 2 parts in 10^7 from -20 to 0°C; clock should be synchronized every 24 h
Battery life:	3 cassette tapes worth of recording (conservative estimate); batteries (lead-acid) can be recharged
Cassette capacity:	about 23 to 24 min (i.e. about 14 99-s records)
Geophones:	Mark Products L4 (2 Hz, vertical component)
Minimum operating temperature:	25°F (limited by lubricant in cassette tapes)

multiple Omega receiver system (i.e. receiving the time signals from several Omega transmitters around the world), while the others were tuned to the frequency of the Omega transmitter La Réunion, which is closest to the target area. The quality of the Omega signals was tested during a pre-site survey in 1989 together with the transmission of short-wave signals for some telemetered sites which were planned to be installed in some remote areas such as around Mt. Kenya.

For the headquarters at Nakuru a big house was rented which housed the computer facilities for preprocessing the recorded data and served as home base for the maintenance crews, consisting of European and American scientists, technicians and students and Kenyan students. All stations had to be serviced at intervals of 4–10 days depending on how long battery and/or storage capacity lasted. Four to six people were always in the field at a time servicing the stations. Kenyan students, always four at a time for a period of about 6–10 weeks, were trained to operate and maintain the instruments and to use the computer facilities.

7. Data processing and interpretation

7.1. Refraction data

The 186 SGR instruments recorded digitally at 500 samples/s. The remainder of the data, recorded by 20 analogue stations, were digitized with the same sampling rate and processed into the same format as the SGR data. All data were then merged into a single data set. Digital processing included clock drift corrections, de-spiking and frequency filtering before plotting the data in the form of reduced time–distance record sections. P-wave record sections were plotted with reduction velocities of 6 km/s for all shots on all deployments, and a selection was also plotted with higher velocities to enhance mantle phases. Also S-wave record sections were plotted with a reduction velocity of 3.46 km/s and a time scale equal to that of the P-sections divided by 1.73. Together with tables on the shot and recording sites, all record sections were compiled in a data report (KRISP Working Group, 1991). Following phase correlation and identification, initial inter-

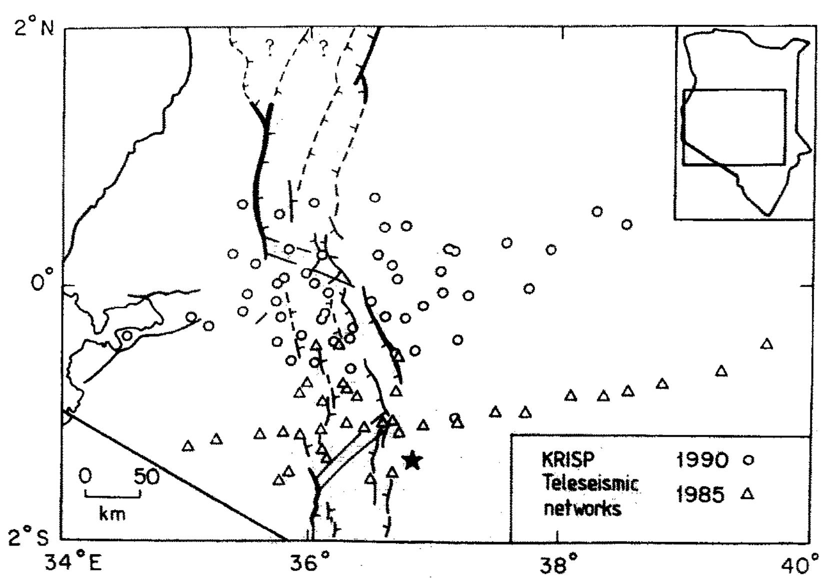

Fig. 5. The KRISP 85 and KRISP 90 teleseismic networks. * = Nairobi, dot = Nakuru.

Table 7
Recording sites of KRISP 85 and KRISP 90 networks (shown in Fig. 5)

Station	Latitude	Longitude	Elevation (m)	Station	Latitude	Longitude	Elevation (m)
Kt01	1°26.32′S	36°39.27′E	1980	KR19	0°31.49′S	36°41.13′E	3100
Kt02	1°29.48′S	36°28.49′E	1020	KR22	0°13.43′N	36°35.00′E	1850
Kt03	1°20.86′S	36°8.11′E	1430	KR24	0°10.08′S	36°37.83′E	2580
Kt04	1°26.80′S	35°50.58′E	1850	KR25	0°28.50′S	36°49.25′E	2440
Kt05	1°2.91′S	36°35.25′E	1750	KR26	0°28.83′N	36°44.27′E	1790
Kt06	1°3.17′S	36°17.74′E	1640	KR27	0°8.01′S	36°53.30′E	1920
Kt07	1°9.04′S	35°54.95′E	1910	KR29	0°2.09′S	37°1.80′E	2400
Kt08	0°48.43′S	36°40.70′E	2500	KR30	1°1.47′S	37°9.82′E	1475
Kt09	0°47.17′S	36°16.94′E	1920	KR31	0°4.07′S	37°14.73′E	2270
Kt10	0°44.53′S	35°58.40′E	2770	KR32	0°21.41′N	37°32.98′E	2020
Kt11	0°49.06′S	35°54.05′E	2460	KR34	0°0.11′S	37°43.88′E	1170
Kt13	0°27.65′S	36°13.18′E	1790	KR35	0°17.20′N	37°53.01′E	2220
Kt14	0°27.92′S	36°2.12′E	2060	W40	0°14.78′N	35°20.96′E	2280
Kt15	0°53.40′S	36°5.76′E	2880	W41	0°3.30′S	35°28.46′E	2440
Kt16	0°44.65′S	36°15.73′E	1920	W42	0°6.48′S	35°42.68′E	2853
Kt17	0°31.40′S	36°39.85′E	3200	W43	0°25.08′S	35°43.86′E	2820
Kt18	1°2.67′S	36°41.18′E	2220	W44	0°33.92′S	35°50.13′E	2800
Kt20	1°16.14′S	36°6.28′E	1670	W45	0°17.70′N	35°48.20′E	1810
Kt22	1°30.41′S	35°49.35′E	2000	W46	0°34.54′S	36°1.92′E	2568
Kt24	1°7.74′S	35°46.92′E	1920	W47	0°14.34′N	36°4.35′E	1160
Kt25	1°5.28′S	36°25.44′E	1595	W48	0°3.25′S	36°7.29′E	1750
Kt26	1°3.48′S	36°53.94′E	1650	W50	0°19.66′S	36°19.17′E	2570
Kt27	1°7.08′S	36°42.78′E	2100	W51	0°6.39′S	36°27.46′E	2560
Kt28	1°5.76′S	36°4.96′E	2090	W52	0°3.74′N	36°40.38′E	1960
Kt31	1°14.11′S	35°1.38′E	1680	W53	0°7.00′N	37°1.30′E	1800
Kt32	1°11.20′S	35°15.00′E	1780	W54	0°24.00′S	37°10.00′E	1980
Kt33	1°9.12′S	35°35.00′E	1920	W55	0°9.97′N	35°31.57′E	2590
Kt39	1°1.47′S	37°9.78′E	1470	W56	0°15.00′N	36°31.00′E	1870
Kt40	0°58.05′S	37°28.36′E	1130	W59	0°3.73′N	35°46.25′E	1982
Kt41	0°57.84′S	37°42.57′E	1100	W61	0°18.07′N	37°5.35′E	2160
Kt42	0°49.91′S	38°5.13′E	960	L01	0°24.61′N	35°34.83′E	2438
Kt43	0°49.80′S	38°20.34′E	770	L02	0°25.68′N	35°37.10′E	1240
Kt45	0°43.98′S	38°48.57′E	570	L03	0°27.79′N	35°40.22′E	1340
Kt46	0°37.65′S	39°16.73′E	290	L04	0°30.19′N	35°44.82′E	1970
Kt47	0°25.25′S	39°37.88′E	140	L07	0°29.89′N	35°54.48′E	1250
KR01	0°22.78′S	34°31.34′E	1290	L10	0°35.00′N	35°79.73′E	1020
KR03	0°17.57′S	35°9.90′E	1750	L11	0°37.83′N	36°2.12′E	1000
KR04	0°11.37′S	35°26.23′E	2090	L12	0°36.42′N	36°2.86′E	980
KR06	0°2.17′N	35°43.35′E	2195	L13	0°37.23′N	36°3.90′E	980
KR07	0°14.48′S	35°44.75′E	2430	L14	0°38.50′N	36°4.11′E	980
KR08	0°34.05′N	35°42.57′E	1640	L15	0°38.75′N	36°5.76′E	1000
KR09	0°22.12′S	35°55.38′E	2290	L16	0°41.87′N	36°5.35′E	1040
KR10	0°38.65′N	36°0.35′E	1110	L17	0°43.00′N	36°8.76′E	1080
KR11	0°1.69′N	36°0.83′E	1690	L19	0°47.38′N	36°16.66′E	1320
KR12	0°6.07′S	35°56.32′E	1710	L21	0°41.12′N	35°30.58′E	2340
KR15	0°37.44′S	36°18.03′E	2330	L23	0°43.65′N	35°50.30′E	2200
KR16	0°24.12′N	36°17.43′E	2120	L26	0°25.33′N	35°57.69′E	1158
KR17	0°51.05′S	36°22.10′E	1997	L27	0°25.89′N	36°4.71′E	1020

Name, coordinates, and distance relative to an array center used for the inversion modelling.
The letters of the station name indicate by which institution the corresponding stations were operated:
Kt = Universities of Wisconsin, Karlsruhe and UCLA (University of California at Los Angeles) in 1985. KR = UCLA and Karlsruhe in 1989/90. W = Wisconsin in 1989/90. L = Leicester in 1989/90.

pretation has been carried out mainly using 2-D ray-tracing methods to model both travel times and amplitudes.

7.2. Teleseismic data

A first data selection and preprocessing of the recorded events was undertaken at the Nakuru headquarters during the field operation. For this the U.S. Geological Survey PDE-listings (Preliminary Determination of Epicenters) transmitted by fax from the U.S.A. were used.

Table 9 and Fig. 6 show the location and distribution of the teleseismic events both for the 1985 and the 1989–90 recording periods which were recorded by more than five stations. These events were used for the subsequent inversion modelling (Achauer et al., 1994-this volume; Slack and Davis, 1994-this volume). Due to the location of the arrays relative to the major earthquake

Table 8
Instrumentation used in the KRISP 85/90 teleseismic surveys

Number 85/90	Type of instrument	Seismometers	Sampling frequency	Institution
3/14	PCM 5800 Lennartz 3 comp.	9:Z:S13 (1 Hz) Geotech H:SH-1 (5 s) Kinemetrics 5: Lennartz LE-3D (1 Hz) (1990 only)	50	University of Karlsruhe
–/3	SED analogue 3 comp.	L4-A-3D (1 Hz) Mark Products	[a]	ETH Zürich/ Karlsruhe [b]
14/14	DL1 3 comp.	HS 10-1 (1 Hz) Hall Sears	25	University of Wisconsin
–/5	REFTEK 3 comp.	L4-A-3D (1 Hz) Mark Products	25	PASSCAL/ Wisconsin [b]
10/10	UCLA PCR-1 3 comp.	L4-A-3D (1 Hz) Mark Products	20	UCLA
9/9	UCLA PCR-1 Z telemetered	L4-A (1 Hz) Mark Products	20	UCLA
–/5	MARS 88 Lennartz 3 comp.	Lennartz LE-3D (1 Hz)	62.5	University of Copenhagen/ [b] Karlsruhe
–/3	REFTEK 3 comp.	MK-3 (1 Hz) Willmore	100	Leicester
–/3	PDAS Geotech 3 comp.	S-13 (1 Hz) each channel	100	Leicester
6/5 [c]	Geostore analogue, 3 comp.	MK-3 (1 Hz) Willmore	[a]	Leicester
11/8 [c]	Geostore analogue, Z, telemet.	MK (1 Hz) Willmore		Leicester

[a] Analogue data digitized with 100 samples per second.
[b] Operating institution.
[c] Special seismicity survey at Lake Bogoria (Young et al., 1991).
Z = vertical component, H = 2 horizontal components.

Table 9

Date and location of teleseismic events (shown in Fig. 6) compiled from the recordings of the KRISP 85/90 teleseismic network

Event	Date	Origin time (h:min:s)	Depth (km)	Location	
				latitude	longitude
Fiji	08/28/85	20:50:49.0	629	−21°0.00′N	178°59.40′W
S. Sandwich	08/29/85	6:13:10.8	50	−57°14.58′N	25°19.98′W
Xinjia	08/29/85	23:39:48.8	17	39°26.46′N	−75°27.12′W
N. Philipin	08/30/85	20:27:10.7	29	16°58.92′N	−119°56.28′W
Yunnan	09/01/85	19:7:42.2	10	23°46.14′N	−102°44.28′W
Minahasa	09/01/85	22:25:34.1	83	0°39.90′N	−121°25.80′W
Halmahrea	09/03/85	23:32:47.5	114	1°24.54′N	−128°9.18′W
Bandasea	09/05/85	3:53:12.0	143	−7°21.84′N	−128°28.32′W
Tonga	09/05/85	6:34:58.0	33	−18°33.54′N	173°37.92′W
Ceram	09/07/85	0:22:1.5	26	−3°4.74′N	−130°20.88′W
Ceram	09/07/85	4:40:30.0	24	−3°8.16′N	−130°16.74′W
Greece	09/07/85	10:20:50.2	31	37°26.70′N	−21°14.10′W
Tonga	09/11/85	17:47:31.0	30	−15°21.00′N	173°32.40′W
Xinjin	09/11/85	20:45:49.5	15	39°21.36′N	−75°24.42′W
S. Philipin	09/11/85	22:7:10.7	135	13°35.64′N	−120°53.58′W
Oaxaca	09/15/85	7:57:53.6	63	17°58.80′N	97°9.60′W
Tonga	09/15/85	11:25:5.3	258	−19°13.20′N	175°36.00′W
Tonga	09/15/85	17:31:0.6	81	−16°48.00′N	174°52.20′W
Sumba	09/15/85	22:58:42.6	39	−10°48.54′N	−119°17.88′W
Tonga	09/16/85	2:54:2.0	139	−15°17.76′N	174°9.18′W
Tonga	09/19/85	8:6:21.0	302	−18°3.60′N	175°32.40′W
Taiwan	09/20/85	15:1:23.5	18	24°35.58′N	−122°16.80′W
Guerrera	09/21/85	1:37:15.1	42	17°48.60′N	101°41.40′W
C. Atlantic	09/22/85	18:23:12.2	10	12°30.60′N	44°18.96′W
Banda	09/24/85	20:28:52.4	147	−6°24.30′N	−130°2.22′W
C. Atlantic	09/25/85	7:6:45.7	10	12°26.58′N	44°19.98′W
Tonga	09/26/85	4:16:22.0	41	−16°0.00′N	173°12.00′W
Kermadec	09/26/85	7:27:47.0	16	−34°36.60′N	178°34.20′W
Solomon	09/27/85	3:39:8.8	33	−9°48.60′N	−159°51.00′W
Crete	09/27/85	16:39:48.7	61	34°30.36′N	−26°35.94′W
Tonga	09/28/85	5:50:39.0	18	−20°54.60′N	174°5.40′W
Yugoslavia	09/28/85	14:50:15.2	7	41°34.86′N	−22°15.24′W
S. Philipin	10/01/85	10:1:44.8	119	13°40.14′N	−120°45.96′W
Hindu Kush	10/02/85	21:31:36.4	217	36°28.38′N	−70°8.34′W
Afghanistan	10/03/85	18:7:38.2	80	36°30.00′N	−71°36.24′W
Malaga	10/04/85	15:17:7.1	10	−18°18.24′N	−48°25.98′W
Canada	10/05/85	15:24:2.2	10	62°14.22′N	124°13.56′W
Vanuatu	10/06/85	12:0:49.2	273	−18°57.66′N	−169°25.92′W
Java	10/09/85	1:15:4.6	154	−6°47.46′N	−107°4.92′W
Alaska	10/09/85	9:33:32.4	30	54°45.90′N	159°36.78′W
Fiji	10/12/85	2:12:57.9	155	−21°39.36′N	176°22.92′W
El Salvador	10/12/85	20:29:20.8	42	13°9.24′N	89°43.20′W
C. Atlantic	10/12/85	22:20:38.0	10	0°55.02′N	29°55.26′W
Tajik	10/13/85	15:59:51.2	16	40°18.06′N	−69°49.38′W
N. Atlantic	10/18/85	1:44:28.9	10	56°45.42′N	34°7.14′W
Carlsberg	10/18/85	16:55:30.9	10	4°27.24′N	−62°39.60′W
S. Philipin	10/19/85	20:51:20.8	42	10°27.60′N	−125°9.42′W
Kermadec	10/20/85	21:36:40.1	256	−29°0.72′N	178°46.38′W
Java	10/25/85	6:47:4.7	10	−9°12.18′N	−105°35.70′W
Banda	10/25/85	18:12:19.5	596	−7°4.62′N	−124°17.04′W
Algeria	10/27/85	19:34:57.1	10	36°27.60′N	−6°45.66′W
Tanimb	10/28/85	10:28:14.5	33	−7°19.86′N	−130°51.00′W
Tonga	10/28/85	12:52:31.2	33	−15°24.00′N	175°59.40′W
Sumatera	10/29/85	5:19:26.4	33	−5°42.78′N	−103°6.60′W

Table 9 (continued)

Event	Date	Origin time (h:min:s)	Depth (km)	Location	
				latitude	longitude
Iran	10/29/85	13:13:44.6	53	36°40.86′N	−54°45.00′W
Tonga	11/04/85	22:43:25.0	144	−17°0.60′N	174°37.80′W
S. Sandwich	11/06/85	8:15:39.6	132	−58°42.96′N	26°13.38′W
Tonga	11/06/85	22:16:16.9	50	−16°22.20′N	173°16.20′W
Turkey	11/07/85	8:26:21.4	33	40°18.60′N	−42°18.42′W
New Zealand	11/07/85	19:12:31.8	49	−35°12.60′N	179°19.20′W
Timor	11/09/85	12:56:12.1	26	−9°49.08′N	−123°44.34′W
Greece	11/09/85	23:30:42.9	22	41°15.72′N	−23°59.28′W
S. Atlantic	11/10/85	19:40:34.0	10	−29°0.60′N	13°9.90′W
S. Atlantic	11/14/85	2:11:45.6	10	−28°54.72′N	13°6.54′W
S. Atlantic	11/16/85	1:56:43.1	10	−47°8.58′N	13°23.82′W
M. Ind. Rise	11/16/85	4:12:18.8	10	−38°34.62′N	−78°22.08′W
Irian Jaya	11/17/85	9:40:21.2	10	−1°38.34′N	−134°54.66′W
S. Atlantic	11/18/85	18:18:34.7	10	−32°17.88′N	13°21.84′W
Java	11/20/85	2:49:44.8	33	−10°26.94′N	−111°49.02′W
Molucca	11/21/85	2:27:18.7	68	2°22.44′N	−126°43.74′W
Albania	11/21/85	21:57:14.9	25	41°42.18′N	−19°23.28′W
S. Sandwich	11/24/85	21:32:41.8	37	−59°27.00′N	24°50.52′W
Java	11/25/85	16:26:30.4	68	−8°38.94′N	−108°29.70′W
Vanuatu	11/28/85	2:25:42.6	33	−14°1.80′N	−166°13.20′W
Vanuatu	11/28/85	3:49:55.5	43	−13°58.80′N	−166°6.00′W
Vanuatu	11/28/85	6:37:47.0	25	−13°51.00′N	−166°15.60′W
At.-Ind. Oc.	11/30/85	2:28:11.5	10	−29°14.10′N	−61°15.18′W
Tonga	11/30/85	3:4:18.8	165	−16°21.96′N	174°11.82′W
Talaud	12/14/85	6:46:11.7	22	3°40.98′N	−126°36.00′W
Arabia	12/14/85	18:13:31.5	10	14°42.72′N	−57°59.94′W
Banda	12/06/89	5:19:46.1	97	−6° − 13.32′N	−130° − 27.54′W
Iran	12/07/89	12:59:32.6	10	25°56.58′N	−59° − 0.12′W
Burma	12/08/89	0:4:25.3	47	21°13.08′N	−93° − 48.00′W
Philipines	12/08/89	10:23:11.3	33	10°4.26′N	−126° − 30.78′W
Minahasa	12/09/89	20:38:8.5	154	0°11.04′N	−123° − 27.36′W
Tonga	12/11/89	17:28:48.2	33	−17° − 12.60′N	172°13.80′W
Banda	12/12/89	8:33:55.5	72	−4° − 42.30′N	−130° − 52.14′W
Philipines	12/15/89	18:43:46.0	33	8°23.58′N	−126° − 46.68′W
Philipines	12/16/89	0:33:36.4	33	8°26.52′N	−127° − 3.96′W
Philipines	12/16/89	0:53:45.7	33	8°25.62′N	−126° − 57.00′W
W. Irian	12/16/89	2:40:48.3	33	−3° − 37.14′N	−131° − 13.38′W
S. India	12/17/89	3:12:15.6	10	−8° − 32.76′N	−92° − 12.54′W
C. Atlantic	12/18/89	7:13:2.5	18	1°1.02′N	29°0.78′W
Philipines	12/20/89	0:8:25.6	64	8°7.80′N	−126° − 52.74′W
Philipines	12/20/89	8:35:20.6	42	8°12.18′N	−126° − 56.10′W
Sumatera	12/21/89	8:8:6.2	33	3°10.56′N	−96° − 25.20′W
S. Sandwich	12/25/89	14:50:57.1	33	−59° − 28.68′N	25°44.10′W
Halmahera	12/25/89	19:50:19.1	105	1°41.22′N	−127° − 10.68′W
Molucca	12/27/89	4:19:45.1	78	0°57.54′N	−126° − 9.54′W
Sumatera	12/27/89	19:24:11.9	90	−4° − 46.80′N	−103° − 19.20′W
Sumatera	12/27/89	20:1:4.0	57	−4° − 25.68′N	−102° − 57.78′W
Tonga	12/29/89	14:36:48.9	274	−18° − 39.72′N	175°31.50′W
Philipines	01/02/90	1:25:6.8	42	8°19.56′N	−127° − 26.58′W
Ceram	01/02/90	21:38:18.4	33	−2° − 35.22′N	−127° − 44.64′W
Somoa	01/04/90	5:32:25.4	83	−15° − 2.76′N	172°54.24′W
Java	01/05/90	10:10:21.4	27	−8° − 45.00′N	−106° − 31.62′W
Arabia	01/05/90	11:59:54.3	10	12°23.70′N	−57° − 53.52′W
S. India	01/06/90	21:44:55.6	10	−10° − 40.44′N	−93° − 1.14′W
At.-Ind. Oc.	01/07/90	20:53:29.0	10	−32° − 11.76′N	−57° − 26.22′W

Table 9 (continued)

Event	Date	Origin time (h:min:s)	Depth (km)	Location	
				latitude	longitude
Tonga	01/08/90	4:17:39.4	33	−17° −40.20′N	172°31.80′W
Tibet	01/09/90	2:29:21.2	33	28°6.60′N	−88° −7.74′W
Fox Isl.	01/09/90	4:58:38.8	33	52°1.08′N	169°21.78′W
Burma	01/09/90	18:51:28.9	118	24°44.88′N	−95° −16.62′W
Burma	01/10/90	6:37:54.5	85	24°32.28′N	−94° −40.86′W
Sw. Africa	01/10/90	10:6:1.4	10	−52° −12.36′N	−13° −33.48′W
Adaman	01/10/90	11:53:21.2	33	11°36.18′N	−95° −11.22′W
Timor	01/10/90	16:11:45.6	39	−10° −17.22′N	−123° −40.62′W
Taluad	01/12/90	15:28:15.0	66	4°58.56′N	−126° −27.84′W
Tonga	01/13/90	17:2:9.6	313	−18° −19.20′N	175°55.20′W
Sumba	01/13/90	20:3:41.5	35	−10° −13.02′N	−117° −47.04′W
Qinghan	01/14/90	3:3:19.0	17	37°46.02′N	−91° −53.64′W
Kermadec	01/18/90	12:45:26.0	26	−29° −59.94′N	177°42.36′W
Sumatera	01/22/90	17:26:12.1	51	3°50.88′N	−96° −6.18′W
Philipines	01/24/90	19:33:31.0	23	14°34.92′N	−119° −27.30′W
Sunda	01/28/90	3:58:47.1	83	−5° −57.60′N	−105° −38.40′W
Fiji	02/02/90	18:34:46.7	576	−17° −56.16′N	178°22.68′W
Java	02/04/90	7:58:14.0	47	−10° −14.58′N	−110° −18.66′W
Afghanistan	02/05/90	5:16:45.1	102	37°4.14′N	−71° −16.38′W
Philipines	02/08/90	7:15:32.3	31	9°41.46′N	−124° −42.48′W
Philipines	02/08/90	7:39:50.8	33	9°39.48′N	−124° −50.46′W
Philipines	02/08/90	7:47:0.1	34	9°43.56′N	−124° −38.58′W
Algeria	02/09/90	9:31:47.8	12	36°44.82′N	−2° −25.56′W
S. Atlantic	02/12/90	23:56:36.6	30	−31° −9.12′N	48°18.66′W
Minahasa	02/15/90	0:27:13.1	232	0° −25.92′N	−123° −40.14′W
Ryukyu	02/17/90	2:28:0.2	50	29°30.00′N	−130° −47.76′W
New Zealand	02/19/90	5:34:37.4	23	−40° −18.00′N	−176° −2.70′W
Vanuatu	02/19/90	6:48:13.2	36	−15° −24.66′N	−166° −17.82′W
Tonga	02/19/90	16:46:33.2	33	−16° −14.40′N	173°57.00′W
M. Ind. Rise	02/22/90	16:51:50.4	10	−11° −30.48′N	−66° −20.58′W
Tonga	02/24/90	19:13:15.4	33	−15° −16.80′N	175°27.18′W
Fiji	03/03/90	12:16:26.9	33	−22° −2.46′N	−175° −9.36′W
Tonga	03/03/90	21:26:24.0	33	−22° −12.60′N	174°9.60′W
Vanuatu	03/04/90	17:21:46.1	33	−15° −21.42′N	−167° −49.20′W
Pakistan	03/04/90	19:46:22.1	28	28°52.32′N	−66° −20.94′W
Vanuatu	03/05/90	16:38:15.0	33	−18° −8.04′N	−167° −56.94′W
Kashmir	03/05/90	20:47:3.5	33	36°51.00′N	−73° −0.54′W
Afghanistan	03/05/90	23:4:23.7	33	36°44.58′N	−72° −58.44′W
Sumba	03/06/90	13:30:59.1	33	−11° −17.88′N	−117° −29.28′W
Kashmir	03/06/90	18:7:6.1	33	36°52.92′N	−73° −6.24′W
Kashmir	03/06/90	21:39:51.3	33	36°51.90′N	−73° −5.28′W
Mascarene I	03/07/90	18:22:3.4	10	−17° −19.86′N	−66° −38.34′W
M. Ind. Rise	03/11/90	0:55:31.0	10	−37° −12.18′N	−78° −9.90′W
Andreanoff	03/12/90	14:41:21.9	33	51°23.46′N	174°58.02′W
Laptev Sea	03/13/90	0:32:58.9	16	73°18.84′N	−134° −57.30′W
Somoa	03/13/90	1:4:50.2	33	−16° −42.96′N	172°23.40′W
Celebes	03/14/90	3:44:49.1	640	4°35.70′N	−122° −37.02′W
Vanuatu	03/15/90	4:56:34.5	131	−15° −9.06′N	−167° −14.94′W
Mascarene I	03/18/90	23:19:29.0	20	−20° −26.88′N	−66° −45.66′W
Kermadec	03/21/90	16:46:6.6	153	−31° −7.08′N	179°12.60′W
Tonga	03/17/90	17:20:18.4	33	−16° −15.30′N	173°1.08′W
Nicaragua	04/03/90	22:57:0.6	53	11°23.82′N	86°23.28′W
Somoa	04/06/90	6:9:1.8	33	−15° −27.06′N	172°0.30′W
S. Sandwich	04/06/90	7:52:1.0	33	−60° −30.48′N	25°29.16′W
Tonga	04/06/90	14:31:45.9	33	−21° −46.86′N	174°9.54′W
Java	04/10/90	22:44:43.0	33	−10° −34.32′N	−109° −34.32′W

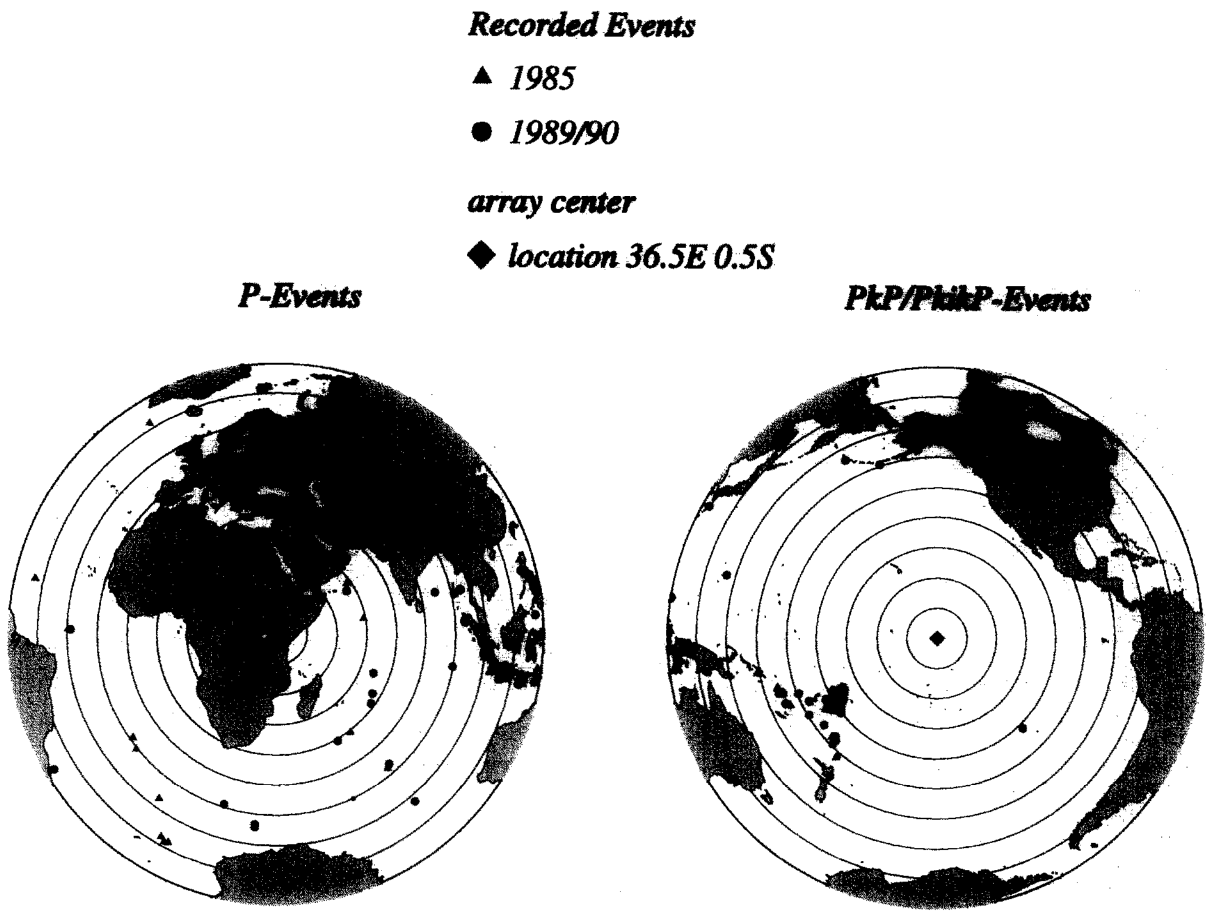

Fig. 6. Azimuthal equidistant maps related to the center of the KRISP 85/90 teleseismic network (36°30′E, 0°25′S: diamond) showing epicenters of the 185 events compiled and listed in Table 9. The distribution of events primarily reflects the regions with the greatest occurrence of moderate and large earthquakes. Teleseismic events recorded by the KRISP network range from approximately (a) 25° to 95° (*P*), (b) 125° to 165° (*PkP* and *PkikP*). Triangles are events recorded in 1985, circles are events recorded in 1989–90.

concentrations around the earth, a relatively uneven distribution of events resulted, with the majority of events in northerly and easterly directions.

All data from 85 stations (see Table 6) were merged into a single data set. Digital data processing included clock corrections, converting the different recording formats into one format (SAC: Seismic Analyzing Code, courtesy of Livermore National Laboratories), de-spiking and frequency filtering (see Ritter, 1991, for a flow chart of the various steps). This data set has been distributed to the participating institutions and is the basis for several investigations currently being carried out and reported on in this volume (e.g., Achauer et al., 1994-this volume; Ritter and Achauer, 1994-this volume; Slack and Davis, 1994-this volume).

7.3. Workshops

To coordinate the interpretation efforts of the many groups involved in the project, workshops were organized to guide discussions towards a joint interpretation. The first KRISP-Workshop was held at Malsch near Karlsruhe, Germany, in August 1990 and aimed at a first interpretation of the seismic-refraction data and an initial set of crustal models (KRISP Working Party, 1991). The second KRISP-Workshop was held in San Francisco in December 1990 and coordinated the refraction and teleseismic interpretation efforts. The third KRISP-Workshop was held in August 1991 at Leinsweiler near Karlsruhe, Germany. It included the refraction and teleseismic groups as well as groups with geologic, tectonic, geothermal, gravity and basin modelling interests. This third workshop provided the basis for the contributions presented in this special volume.

8. Conclusions

The KRISP 90 experiment was one of the largest integrated seismic programmes ever carried out anywhere in the world. It was a great success and provided an excellent data base for the study in detail of the crustal and upper-mantle structure of the Kenya rift.

The project combined, and required, a great variety of experience, expertise, local knowledge, equipment, and laboratory facilities and was beyond the means of any single country. It demanded meticulous planning and team work by a group of 70 individual scientists and reflects great credit on the team, each member of which carried a considerable responsibility.

The results from KRISP will be described in detail in the following papers and its conclusions (Keller et al., 1994b-this volume; Mechie et al., 1994a-this volume) will form the basis for future research including the establishment of a permanent seismic network in the rift area as a contribution to the International Decade of Natural Disaster Reduction (I.D.N.D.R.) and the establishment of a geodetic high-precision network to monitor recent crustal movements. The results will serve as a guide for further exploration in the field of mineral resources and geothermal energy and will serve as a basis for a Global Geoscience Transect through Kenya.

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