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Meeting report: Harnessing Volcanic and Geothermal Resources for Sustainable Development in the East African Rift

Open Report OR/18/065

BRITISH GEOLOGICAL SURVEY

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Meeting report: Harnessing Volcanic and Geothermal Resources for Sustainable Development in the East African Rift

C.A. Rochelle

Keywords

Volcanic; geothermal; resources, East African Rift; workshop; Kenya.

Front cover

A gorge exposing layered pumice deposits at the Hells Gate National Park next to the Olkaria Geothermal Field. Note the volcanic plug at the top of the image, which was fed by the glassy feeder dyke in the centre of the image.

Bibliographical reference

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Foreword

This report is the published product of the British Geological Survey (BGS) and summarises key observations from a workshop held at Niavasha, Kenya, 17-20 September 2018. Its primary purpose was as a ‘getting to know you’ workshop focused on sharing knowledge about volcanoes and geothermal in the East African Rift. This was made possible because of a £25k Global Challenges Research Fund grant awarded Prof David Pyle of Oxford University, who linked with Prof Nicholas Marita of Dedan Kimathi University of Technology, Nairobi. This allowed 6 UK participants to travel to Kenya for the meeting, and approximately three times that number to attend from a range of countries along the East African Rift.

Acknowledgements

The Global Challenges Research Fund is gratefully acknowledged for providing funding to allow this workshop to happen. Especially thanked are Dr Karen Fontijn (University of Oxford, UK, now Université Libre de Bruxelles, Belgium), Prof David Pyle (University of Oxford, UK) and Prof Nicholas Marita (Dedan Kimathi University of Technology, Kenya) for their work in arranging and running the meeting.

The workshop was funded by a Global Challenges Research Fund Networking Grant from the Academy of Medical Sciences, grant number GCRFNG100310, 1/2/2018 – 31/1/2019.

The BGS work research was also supported by BGS NC-ODA grant NE/R000069/1 entitled ‘Geoscience for Sustainable Futures’. It was delivered via the BGS Eastern Africa Official Development Assistance (ODA) Research Platform.

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FIGURES

1 Introduction and Background

The East African Rift (EAR) passes through a range of countries and encompasses a range of resources such as geothermal systems, mineralisation and gases. As the region is tectonically active, it also hosts potential hazards, such as active volcanoes. Achieving a better understanding of resource potential is central to furthering the long-term stability and development of these countries. With this in mind, Prof David Pyle of Oxford University submitted a proposal to the Global Challenges Research Fund (GCRF) so that a workshop could be held to bring together leading African and UK scientists with an interest in the sustainable development of volcanic and geothermal resources. This was in conjunction with Prof Nicholas Marita of Dedan Kimathi University of Technology, Nairobi.

A £25k grant was awarded to Prof Pyle, and a workshop was organised at Burch's Resort, Niavasha, Kenya on the 17-20 September 2018. This was entitled 'Harnessing Volcanic and Geothermal resources for Sustainable Development In The East African Rift'. This report describes a summary of that meeting.

The primary purposes of the workshop were to share experience and knowledge of the EAR, and for UK and African researchers to get to know each other better (many had never met before). This was to be achieved through lectures, practical demonstrations, and field visits (see agenda in Appendix 1). The overall aim of the meeting was to help create new opportunities, project ideas and long-term partnerships.

2 Attendees and Science Areas

Six researchers travelled from the UK (4 from Oxford University, 1 from Glasgow University, and 1 from the BGS), and 16 came from Africa from a mixture of Kenya, Ethiopia, Tanzania, Djibuti and the DRC (plus others from Kenya at various times). A full listing of attendees is given in Appendix 2.

Key senior Kenyan academics who were present were:
- Prof Nicholas Marita of Dedan Kimathi University of Technology, Nairobi.
- Prof Daniel Ichang'i of the University of Nairobi.

Though the initial concept was for an equal emphasis on volcanoes and geothermal systems, the meeting turned out to be heavily skewed towards high temperature geothermal systems. The interest from the Oxford University participants was mainly volcanic. Whilst risk was not talked about too much (mainly as the volcanoes interest group was smaller than expected), it was noted that >25M people in Kenya live within 30 km of EAR volcanoes.

3 Agenda

3.1 OVERVIEW OF EAST AFRICAN RIFT GEOLOGY

The first day (described in the agenda as Day 0) was a travel day from Nairobi. However, during the journey we stopped at an escarpment viewpoint and looked out over the East African Rift (Figure 1). Discussion about general rift geology and mechanisms of formation. The Eastern Rift is more active (more magma emplacement, larger magma chambers and compositional differentiation), whereas the Western Rift is more passive (mainly crustal stretching with fewer volcanoes).

Specific discussion about the volcanic geology of Mount Suswa and Mount Longonot. Bimodal distribution of volcanoes and magma composition. Lots of fissure-type eruptions of more basic lava, but where sizable magma chambers build up (under larger volcanoes) differentiation can take place, and more silicic magma is produced (plenty of evidence of obsidian at the surface). There are also high alkali content magmas which produce low viscosity lavas.

The first evening mainly involved an 'icebreaker' session, and this was followed up with short participant introductions the following morning (Figure 2).

3.2 SCIENTIFIC PRESENTATIONS

Day 1 was consisted of sessions of related talks, each of which was about 15 minutes long.

General overview of EAR geology and volcano-related resources:

- Introduction of EAR geology
- Introduction to EAR volcanology and volcanic hazards
- Introduction to EAR geothermal systems
- Introduction to gas monitoring
- Introduction to mineral resources

Geothermal companies:

- Geothermal development Company (GDC)
- KenGen (Olkaria)
- Geothermal Development in Djibouti

Active research projects:

- Volcanic and seismic monitoring in the Western Branch of the EAR
- Update on geothermal exploration/exploitation and direct-use applications in the Kenyan Rift
- RiftVolc – past, present and future volcanism in the Main Ethiopian Rift
- Helium resources in young rift basins surrounding the Tanzanian Craton
- Gas surveys to identify structures at Menengai

Day 2 took more of a forward look towards opportunities.

Future research developments:

- Training of earth sciences in Africa
- UK / Africa / other funding sources
- Industry perspective and collaboration with academia

Breakout groups (Figure 4):

- What are the main research priorities for the next 10 years?
- What are the primary challenges and needs for geoscience in Africa?
- How can international collaborations be improved?

Introduction to field visits:

- Menengai
- Olkaria

Demonstration of gas sampling techniques:

- Oxford University and noble gas methods.
- Glasgow University and soil gas methods.
- BGS and soil gas and noble gas methods.

3.3 FIELD VISITS

These visits were arranged to give us an overview of geothermal operations, and included information on general geology, surveying, drilling, production, powerplant, and environmental monitoring.

3.3.1 Menengai

Day 3 was a visit to the Menengai geothermal site.

This geothermal field lies within a well-defined, approximately 10 km diameter, caldera (Figure 4). This is being developed by the Geothermal Development Company[1] (GDC). The field is in a stage of active development, with over 40 wells drilled feeding an installed capacity of >165 MWe, and currently has 7 large drill rigs on the site (3 were actively drilling at the time of our visit, Figures 5 and 6). Production is only moderate, suggesting either a lower permeability reservoir formation of limited fracturing.

We visited:

- Malima Punda (the highest point within the caldera) for an overview of caldera geology). Last eruption about 200 years ago.
- Direct use of geothermal energy (well MW-03, Figure 5), with small-scale tests ongoing in greenhouses (Figure 7), fish tanks (Figure 8), launderette, and milk pasteurisation.
- Well pad visit to an actively drilling well ([MW-15?] very noisy, were shown round the drilling operations, talked to the site geologist [had long conversation regarding samples and mineralogy]).
- Fumarole visit and demonstration of gas sampling (Figure 9).
- Visit to well pad number 1, with wells under test.
- Road cutting at the edge of the caldera showing a good exposure of pyroclastic deposits.

Items of note from this visit:

- Drilled into molten rock three times at about 2.2 km. No blowouts or pressure problems, just the drills getting stuck as the molten rock sets around them.
- No warning signs of being about to hit magma, which suggests it is relatively young as it has not altered the surrounding rock (last eruption there was about 200 years ago). They have a reasonable idea where the boundary of the suspected ‘dome-like’ magma chamber is, so the drillers stop the wells just 100-200m above the magma chamber.
- There is a clear parallel in terms of scientific interests and opportunities with the Krafla Magma Testbed (KMT). Lots of potential science could be done in terms of magma processes and studies of the glass. Given that there are 7 big rigs on site, one wonders if the ‘KMT concept’ might actually be more workable at Menengai (the ‘MMT’?).
- I did not see samples of the recovered glass, but understand more about the situation there having spoken to the site geologist (who has looked at the glass in thin section).
- Helen Robinson (Glasgow PhD student) has been doing soil gas and resistivity surveys in the area. Whilst this gas survey is constrained by the vegetation in the area, there is scope for both wider area coverage to identify changes towards the edge of the caldera, and also closer-spaced sampling for higher resolution studies.

[1] http://www.gdc.co.ke

3.3.2 Olkaria

Day 4 was a visit to the Olkaria geothermal site.

The Olkaria geothermal field also lies within a ring structure, but it is less well defined than the caldera at Menengai – it is not just a simple caldera. This is run by KenGen[2]. This is a very large and well-developed field, and is the site of the first geothermal powerplant in Kenya (Figure 10). It is split into 8 or so individual production areas, each of which is as large as some other geothermal fields. There are 281 wells over the site, with an installed capacity of capacity >660 MWe. The reservoir has very good permeability over large areas, and production rates rare high.

We visited:

- The Olkaria geothermal spa (Figures 11 and 12)
- The KenGen geoscience labs
- Olkaria II viewpoint
- Demonstration of geochemical sampling (water and gas) (Figure 13)
- Tour of the Ololbutot crater
- Olkaria I power station
- A geothermal well under active fluid production and discharge
- Short tour of the Ol Njorowa Gorge and the Hells Gate National Park (volcanic features, hot springs, lots of animals, Figures 14 1nd 15).

Items of note from this visit:

- Olkaria was Africa's first geothermal plant, and is now a huge complex of about 8 different geothermal prospects.
- KenGen have a very fancy new office at the entrance to the site – looks very much like a 'statement building'. KenGen are working on building a geothermal centre of excellence on adjacent land for geothermal training.
- I saw some of their water and gas monitoring techniques demonstrated. Sampling of produced fluids from the wellhead looked sensible, producing a range of waters and gas samples for analysis. Field gas monitoring techniques were more basic however, and appears somewhat laborious. The BGS methods appear far more efficient, and may deliver a wider range of gas measurements.
- Gas monitoring/surveying to identify the surface expressions of open faults/fractures would be useful, as would fracture mapping.
- Time-series gas monitoring at fixed sites would also be useful to get information on the impact of production over time (e.g. semi-permanent autonomous stations etc, as per what BGS has deployed elsewhere).
- 3D modelling of the site. KenGen have a 3D model of major conductive fractures, but this structural model appears to be quite simple. GIS treatment and focussed new data acquisition would seem to be an opportunity for the BGS.

[2] http://www.kengen.co.ke

4 Key observations from the meeting

The following observations are not in a particular order, though some key points are underlined to highlight them:

- The workshop was a very good opportunity to meet a wide range of African geoscientists from several countries. In particular, it was excellent in terms of meeting Kenyan geoscientists, and good contacts were made with the two key Kenyan geothermal companies, KenGen and GDC.
- KenGen have about 69% of Kenyan electric supply and are nationally owned. They cover everything from site exploration, drilling and power production. GDC are private, and are only allowed to explore and develop sites, selling steam to independent power producers. The relationship between the 2 companies (and with the universities) seemed quite complex. Whilst these companies employed graduates from Kenyan universities, there was clearly a barrier in terms of academic researchers accessing equipment held by the companies.
- The science areas covered during the workshop were broad ranging, but included: lots of gas monitoring, fluid chemistry, geological structures, metal deposit formation, but only some geophysics.
- BGS got several mentions in terms of its historical work in the area and the preliminary geothermal investigations of the 1970s and 80s. The Kenyans were complimentary about the past BGS work, and it appeared that the BGS data underpinned the decisions to exploit the geothermal systems. We should be able to build upon this positive view. Some of the Kenyans only had poor photocopies of the reports.
  Note: There is an easy win in terms of collating good quality digital copies of all the BGS reports from that era and making them available.
- There are several clear areas where we can work with the Kenyans, and these should be investigated further. Possibilities include:
  - Big area surveys of the rift or transects across the rift (e.g. remote sensing, seismics, gas and water monitoring) aimed at (more of an academic) understanding rift processes and possibly also resource evaluation. It seemed to me that there were only limited datasets at this scale, and that wider-scale surveys could highlight areas of interest for more detailed investigation.
  - Surveys focused on specific sites (e.g. high-resolution gas monitoring, thermal imaging) to investigate volcanic or geothermal processes (the former of more academic interest, the latter linked with geothermal exploitation). Also potential for surveys linked to oil/gas, helium, and metals.
    NOTE: Whilst some satellite-based work and INSAR have been done, it is noteworthy that Kenya has just (spring 2018) legalized the use of UAVs – so detailed UAV-based imaging/monitoring of sites may be something BGS could undertake.
    Also, there are only 4 or 5 permanent seismic stations in the country, and they can't detect low intensity events, so developing this infrastructure is an opportunity.
- Menengai: The GDC have drilled into molten rock three times at about 2.2 km. The igneous body appears to be 'dome-shaped'. Lots of potential science could be done in terms of magma processes and studies of the glass samples recovered.
  NOTE: There is potential for cutting edge science here, with clear links to similar BGS interests in Iceland and the KMT. There is a specific potential opportunity for the BGS in terms of high resolution microanalysis and spectroscopic studies. As ideas of what to investigate already exist, this could be geared up relatively quickly.
- Menengai: Some surface gas monitoring data exist, but this is limited in extent.

NOTE: There are opportunities to extend this gas monitoring in terms of area covered, gases analysed and degree of spatial resolution.

- Olkaria: This was Africa's first geothermal plant, and is now a huge complex of about 8 different geothermal prospects. I saw some of their gas monitoring work, it is quite basic – we could do far more, and far more quickly.
  NOTE: There are opportunities for gas monitoring, but this time at a site-scale (or one geothermal prospect at a time). Time-series gas monitoring at fixed sites could also be useful to identify any temporal changes as a result of steam production.

- Olkaria: 3D modelling of the site. KenGen have a 3D model of major conductive fractures, but this structural model appears to be relatively simple (at least from what I saw in their presentation).
  NOTE: There could be opportunities to develop this model further, though a first step would be to conduct a detailed initial assessment of current model. There may be potential for GIS treatment and focussed new data acquisition, which could be an opportunity for the BGS.

- Both Menengai and Olkaria: Many samples of drill chips (and possibly a few cores) are being taken at regular intervals, but it was not clear than anything other than basic optical microscopy was being done on the samples.
  NOTE: There appears much scope for higher resolution studies (such as by SEM), and mineral geothermometry (± fluid inclusions), which are the types of geothermal investigations that the BGS has done in the past.

- It is clear that the academics from the African countries represented at the workshop had very little access to equipment (and in the case of the DRC, even access to field areas on safety grounds). They were keen to utilize the laboratory facilities run by KenGen and the GDC lab - though those companies appeared more reticent to do this.
  NOTE: There is clear potential for any future joint UK-Africa projects to have a component of African students utilizing equipment in the UK (even if most of their work is based in Africa). However, we should be careful to ensure that skills learned can be sustainably transferred to the local situations in Africa (i.e. not accentuate the current 'brain drain' of African researchers because they don't have local access to equipment that they have been trained to use).

- There seems to have been a gap in training geologists in Kenya from about the 1990s – so there is a bit of a skills shortage within mid-career scientists.

- The Rift Valley has held lakes of large size during the geologic past, allowing the build-up of organic-rich sediments. Locally high geothermal gradients have facilitated breakdown of these organics and the liberation of gas and heavier hydrocarbons. Evidence for hydrocarbons is starting to be found in Kenya, which they are keen to exploit if there are sufficient deposits.
  NOTE: Gas monitoring is a clear potential future area of work – both large areal coverage at low resolution, and higher resolution coverage at site-scale.

- There is evidence for other types of gas resources. Unusually high concentrations of helium have been found in vents near the Tanzania craton[3] (>10% helium, with the remainder being nitrogen). A company has been formed to explore for helium resources (it is hoped that a reservoir of free gas will exist at depth).
  In terms of CO_2 resources, there is at least one borehole (in Kenya, at the very edge of the rift escarpment) producing commercial quantities of CO_2. Given the ubiquitous nature of this gas in rift settings, it is very likely that other such accumulations occur.

[3] https://www.nation.co.ke/news/africa/Helium-worth-billions-found-in-Tanzania/1066-3272268-ipj0d8/index.html

NOTE: Again, gas monitoring surveys appear a possible future area of work – both large areal coverage at low resolution, and higher resolution coverage at site scale. Helium could present specific analytical challenges in terms of analysis in the field, and consideration should be given to investing in specific mobile equipment to analyse for it.

- In more southern parts of the EAR, there is increasing interest in exploiting the methane in deep waters in Lake Kivu. This is already being done to some extent in Rwanda, but the DRC would like to do this as well.
  NOTE: There is potential for limnology studies and gas monitoring, plus risk assessments.

Figure 1. On a rift escarpment viewpoint looking out over the East African Rift.

Figure 2. Some of the workshop participants.

Figure 3. A typical breakout group discussion (reproduced with permission of D. Pyle).

Figure 4. At the entrance of the Menengai Geothermal Field.

Figure 5. A large rig drilling a new borehole at the Menengai Geothermal Field. White containers on the right hand side give a sense of scale.

Figure 6. A typical production well at the Menengai Geothermal Field.

Figure 7. Greenhouse close to one of the wells at Menengai, where geothermal water is used to provide heat at night for the growing of capsicums (and previously, tomatoes).

Figure 8. Small ponds used to demonstrate the use of geothermal heat to help rear tilapia.

Figure 9. Examining diffuse areas of gas venting at the Menengai Geothermal Field.

Figure 10. Overview of pipework at power production facilities at the Olkaria Geothermal Field.

Figure 11. Entrance to the geothermal spa at the Olkaria Geothermal Field.

Figure 12. Turquoise geothermal waters in the outside pool at the Olkaria Geothermal Field.

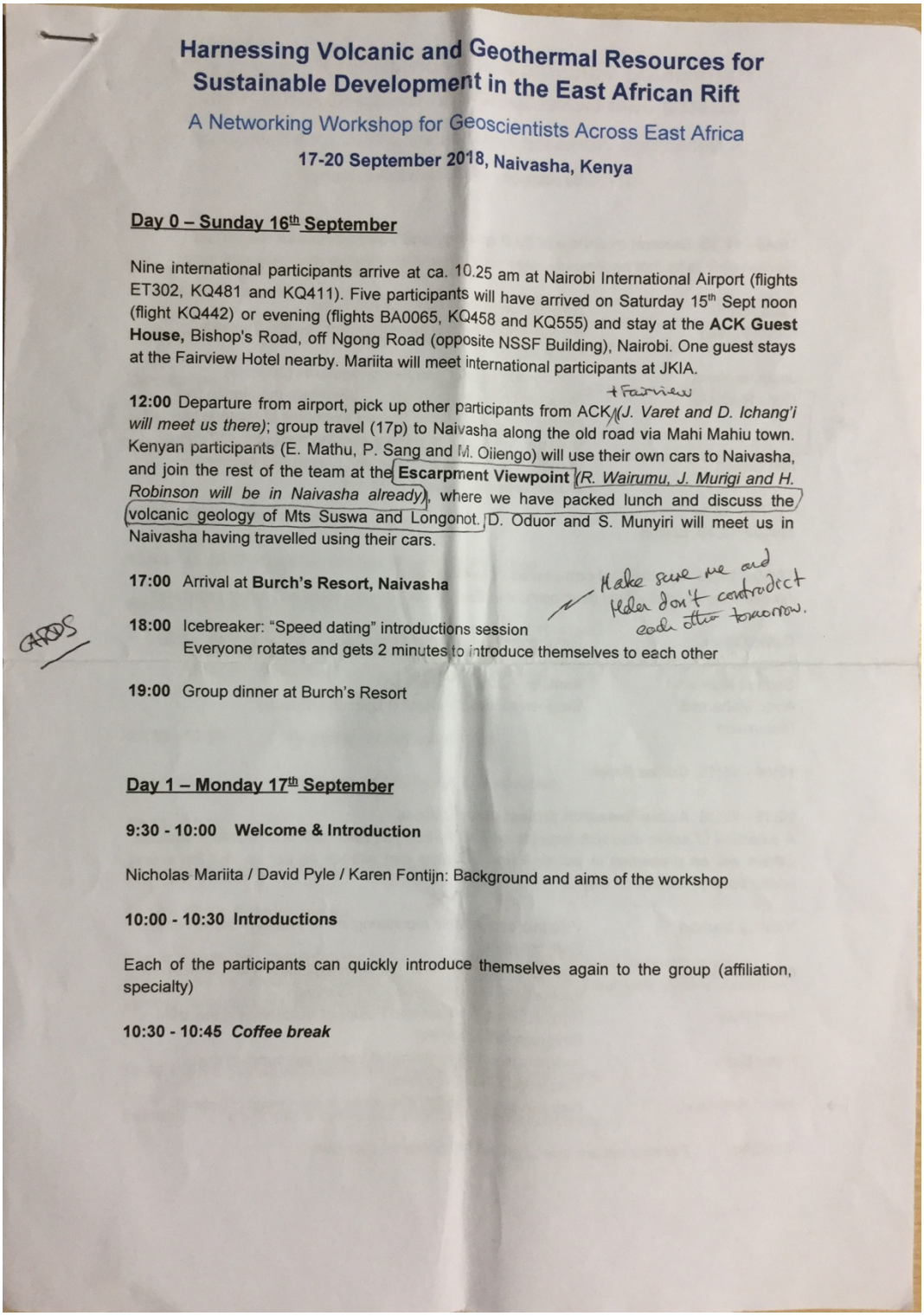
Figure 13. Demonstrating fluid sampling from a pipeline at the Olkaria Geothermal Field.

Figure 14. Walking through a gorge exposing layered pumice deposits at the Hells Gate National Park next to the Olkaria Geothermal Field.

Figure 15. A gorge exposing layered pumice deposits at the Hells Gate National Park next to the Olkaria Geothermal Field. Note the volcanic plug at the top of the image, which was fed by the glassy feeder dyke in the centre of the image.

Appendix 1

Agenda distributed at the workshop (with annotations).



Harnessing Volcanic and Geothermal Resources for Sustainable Development in the East African Rift

A Networking Workshop for Geoscientists Across East Africa

17-20 September 2018, Naivasha, Kenya

Day 0 – Sunday 16th September

Nine international participants arrive at ca. 10.25 am at Nairobi International Airport (flights ET302, KQ481 and KQ411). Five participants will have arrived on Saturday 15th Sept noon (flight KQ442) or evening (flights BA0065, KQ458 and KQ555) and stay at the **ACK Guest House,** Bishop's Road, off Ngong Road (opposite NSSF Building), Nairobi. One guest stays at the Fairview Hotel nearby. Mariita will meet international participants at JKIA.

12:00 Departure from airport, pick up other participants from ACK (+ Fairview) *(J. Varet and D. Ichang'i will meet us there)*; group travel (17p) to Naivasha along the old road via Mahi Mahiu town. Kenyan participants (E. Mathu, P. Sang and M. Oiiengo) will use their own cars to Naivasha, and join the rest of the team at the **Escarpment Viewpoint** *(R. Wairumu, J. Murigi and H. Robinson will be in Naivasha already)*, where we have packed lunch and discuss the volcanic geology of Mts Suswa and Longonot. D. Oduor and S. Munyiri will meet us in Naivasha having travelled using their cars.

17:00 Arrival at **Burch's Resort, Naivasha**

Make sure me and Heler don't contradict each other tomorrow.

GARDS

18:00 Icebreaker: "Speed dating" introductions session
Everyone rotates and gets 2 minutes to introduce themselves to each other

19:00 Group dinner at Burch's Resort

Day 1 – Monday 17th September

9:30 - 10:00 Welcome & Introduction

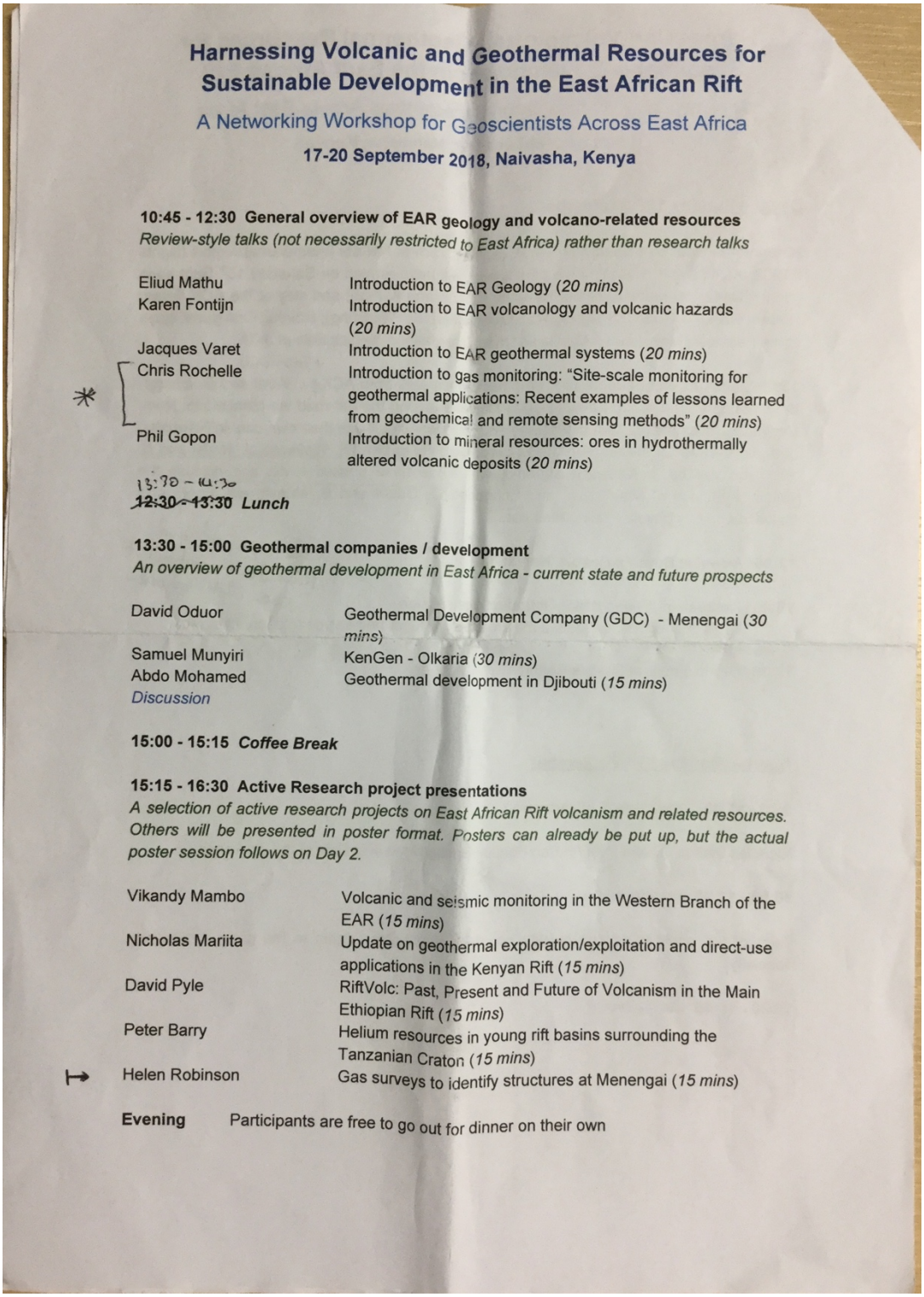
Nicholas Mariita / David Pyle / Karen Fontijn: Background and aims of the workshop

10:00 - 10:30 Introductions

Each of the participants can quickly introduce themselves again to the group (affiliation, specialty)

10:30 - 10:45 ***Coffee break***

Agenda continued.



Harnessing Volcanic and Geothermal Resources for Sustainable Development in the East African Rift

A Networking Workshop for Geoscientists Across East Africa

17-20 September 2018, Naivasha, Kenya

10:45 - 12:30 General overview of EAR geology and volcano-related resources
Review-style talks (not necessarily restricted to East Africa) rather than research talks

Eliud Mathu	Introduction to EAR Geology (*20 mins*)
Karen Fontijn	Introduction to EAR volcanology and volcanic hazards (*20 mins*)
Jacques Varet	Introduction to EAR geothermal systems (*20 mins*)
Chris Rochelle	Introduction to gas monitoring: "Site-scale monitoring for geothermal applications: Recent examples of lessons learned from geochemical and remote sensing methods" (*20 mins*)
Phil Gopon	Introduction to mineral resources: ores in hydrothermally altered volcanic deposits (*20 mins*)

13:30 - 14:30
~~12:30 - 13:30~~ ***Lunch***

13:30 - 15:00 Geothermal companies / development
An overview of geothermal development in East Africa - current state and future prospects

David Oduor	Geothermal Development Company (GDC) - Menengai (*30 mins*)
Samuel Munyiri	KenGen - Olkaria (*30 mins*)
Abdo Mohamed	Geothermal development in Djibouti (*15 mins*)
Discussion	

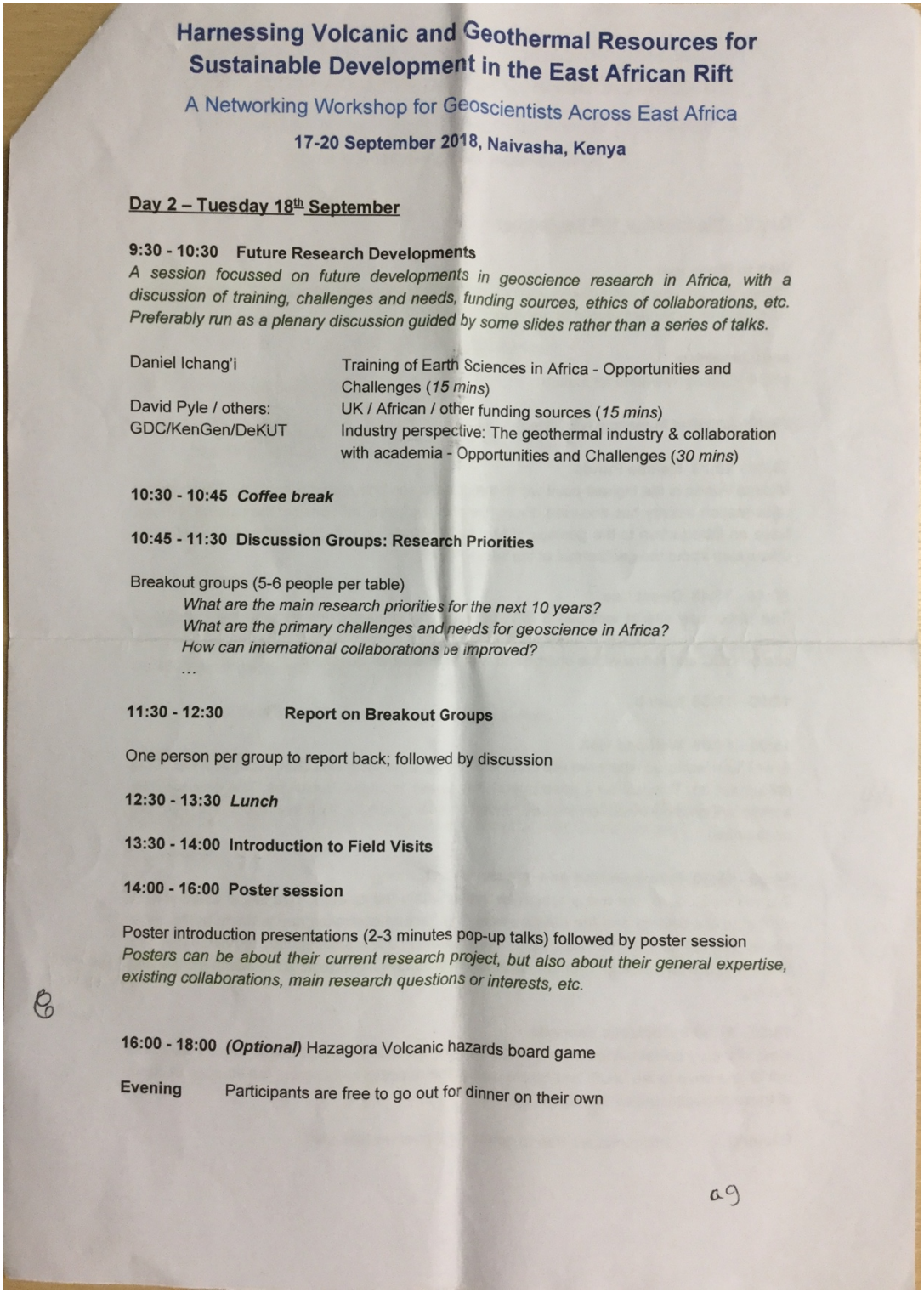
15:00 - 15:15 ***Coffee Break***

15:15 - 16:30 Active Research project presentations
A selection of active research projects on East African Rift volcanism and related resources. Others will be presented in poster format. Posters can already be put up, but the actual poster session follows on Day 2.

Vikandy Mambo	Volcanic and seismic monitoring in the Western Branch of the EAR (*15 mins*)
Nicholas Mariita	Update on geothermal exploration/exploitation and direct-use applications in the Kenyan Rift (*15 mins*)
David Pyle	RiftVolc: Past, Present and Future of Volcanism in the Main Ethiopian Rift (*15 mins*)
Peter Barry	Helium resources in young rift basins surrounding the Tanzanian Craton (*15 mins*)
Helen Robinson	Gas surveys to identify structures at Menengai (*15 mins*)

Evening Participants are free to go out for dinner on their own

Agenda continued.



Harnessing Volcanic and Geothermal Resources for Sustainable Development in the East African Rift

A Networking Workshop for Geoscientists Across East Africa

17-20 September 2018, Naivasha, Kenya

Day 2 – Tuesday 18th September

9:30 - 10:30 Future Research Developments

A session focussed on future developments in geoscience research in Africa, with a discussion of training, challenges and needs, funding sources, ethics of collaborations, etc. Preferably run as a plenary discussion guided by some slides rather than a series of talks.

Daniel Ichang'i	Training of Earth Sciences in Africa - Opportunities and Challenges (*15 mins*)
David Pyle / others:	UK / African / other funding sources (*15 mins*)
GDC/KenGen/DeKUT	Industry perspective: The geothermal industry & collaboration with academia - Opportunities and Challenges (*30 mins*)

10:30 - 10:45 ***Coffee break***

10:45 - 11:30 Discussion Groups: Research Priorities

Breakout groups (5-6 people per table)

What are the main research priorities for the next 10 years?
What are the primary challenges and needs for geoscience in Africa?
How can international collaborations be improved?
...

11:30 - 12:30 Report on Breakout Groups

One person per group to report back; followed by discussion

12:30 - 13:30 ***Lunch***

13:30 - 14:00 Introduction to Field Visits

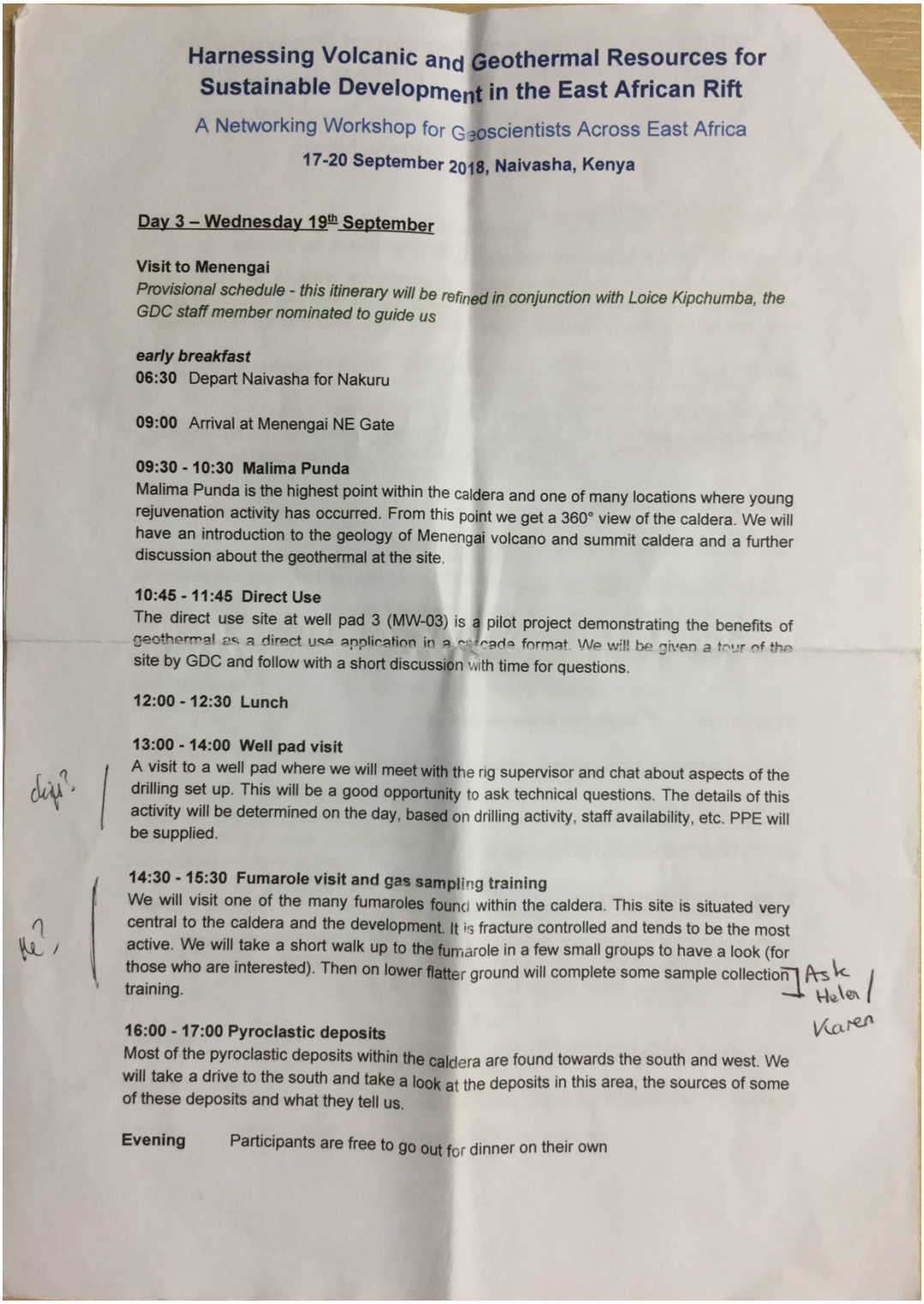
14:00 - 16:00 Poster session

Poster introduction presentations (2-3 minutes pop-up talks) followed by poster session
Posters can be about their current research project, but also about their general expertise, existing collaborations, main research questions or interests, etc.

16:00 - 18:00 ***(Optional)*** Hazagora Volcanic hazards board game

Evening Participants are free to go out for dinner on their own

Agenda continued.



Harnessing Volcanic and Geothermal Resources for Sustainable Development in the East African Rift

A Networking Workshop for Geoscientists Across East Africa

17-20 September 2018, Naivasha, Kenya

Day 3 – Wednesday 19th September

Visit to Menengai

Provisional schedule - this itinerary will be refined in conjunction with Loice Kipchumba, the GDC staff member nominated to guide us

early breakfast

06:30 Depart Naivasha for Nakuru

09:00 Arrival at Menengai NE Gate

09:30 - 10:30 Malima Punda

Malima Punda is the highest point within the caldera and one of many locations where young rejuvenation activity has occurred. From this point we get a 360° view of the caldera. We will have an introduction to the geology of Menengai volcano and summit caldera and a further discussion about the geothermal at the site.

10:45 - 11:45 Direct Use

The direct use site at well pad 3 (MW-03) is a pilot project demonstrating the benefits of geothermal as a direct use application in a cascade format. We will be given a tour of the site by GDC and follow with a short discussion with time for questions.

12:00 - 12:30 Lunch

13:00 - 14:00 Well pad visit

A visit to a well pad where we will meet with the rig supervisor and chat about aspects of the drilling set up. This will be a good opportunity to ask technical questions. The details of this activity will be determined on the day, based on drilling activity, staff availability, etc. PPE will be supplied.

14:30 - 15:30 Fumarole visit and gas sampling training

We will visit one of the many fumaroles found within the caldera. This site is situated very central to the caldera and the development. It is fracture controlled and tends to be the most active. We will take a short walk up to the fumarole in a few small groups to have a look (for those who are interested). Then on lower flatter ground will complete some sample collection training.

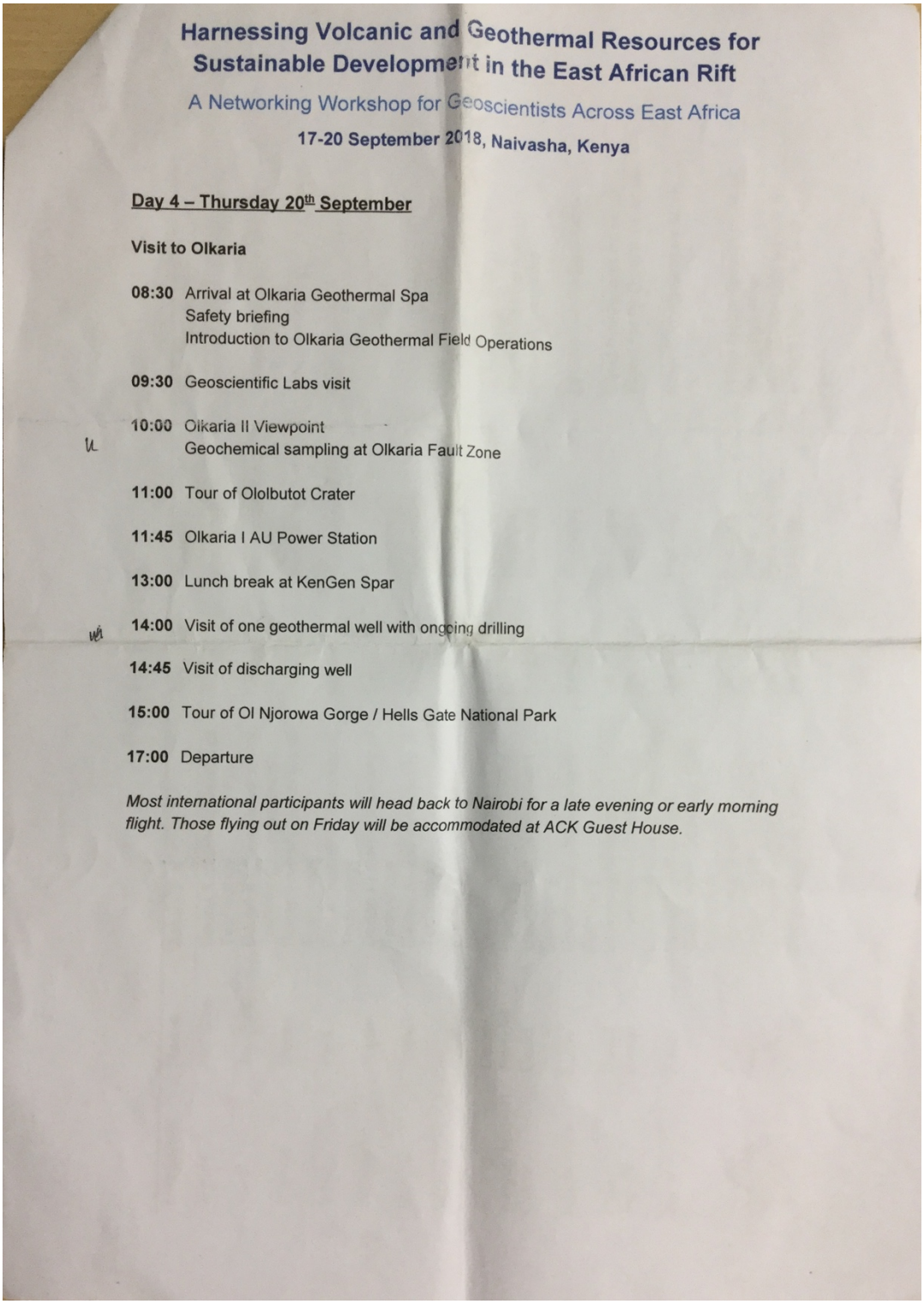
Ask Helen / Karen

16:00 - 17:00 Pyroclastic deposits

Most of the pyroclastic deposits within the caldera are found towards the south and west. We will take a drive to the south and take a look at the deposits in this area, the sources of some of these deposits and what they tell us.

Evening Participants are free to go out for dinner on their own

Agenda continued.



Harnessing Volcanic and Geothermal Resources for Sustainable Development in the East African Rift

A Networking Workshop for Geoscientists Across East Africa

17-20 September 2018, Naivasha, Kenya

Day 4 – Thursday 20th September

Visit to Olkaria

08:30 Arrival at Olkaria Geothermal Spa
Safety briefing
Introduction to Olkaria Geothermal Field Operations

09:30 Geoscientific Labs visit

10:00 Olkaria II Viewpoint
Geochemical sampling at Olkaria Fault Zone

11:00 Tour of Ololbutot Crater

11:45 Olkaria I AU Power Station

13:00 Lunch break at KenGen Spar

14:00 Visit of one geothermal well with ongoing drilling

14:45 Visit of discharging well

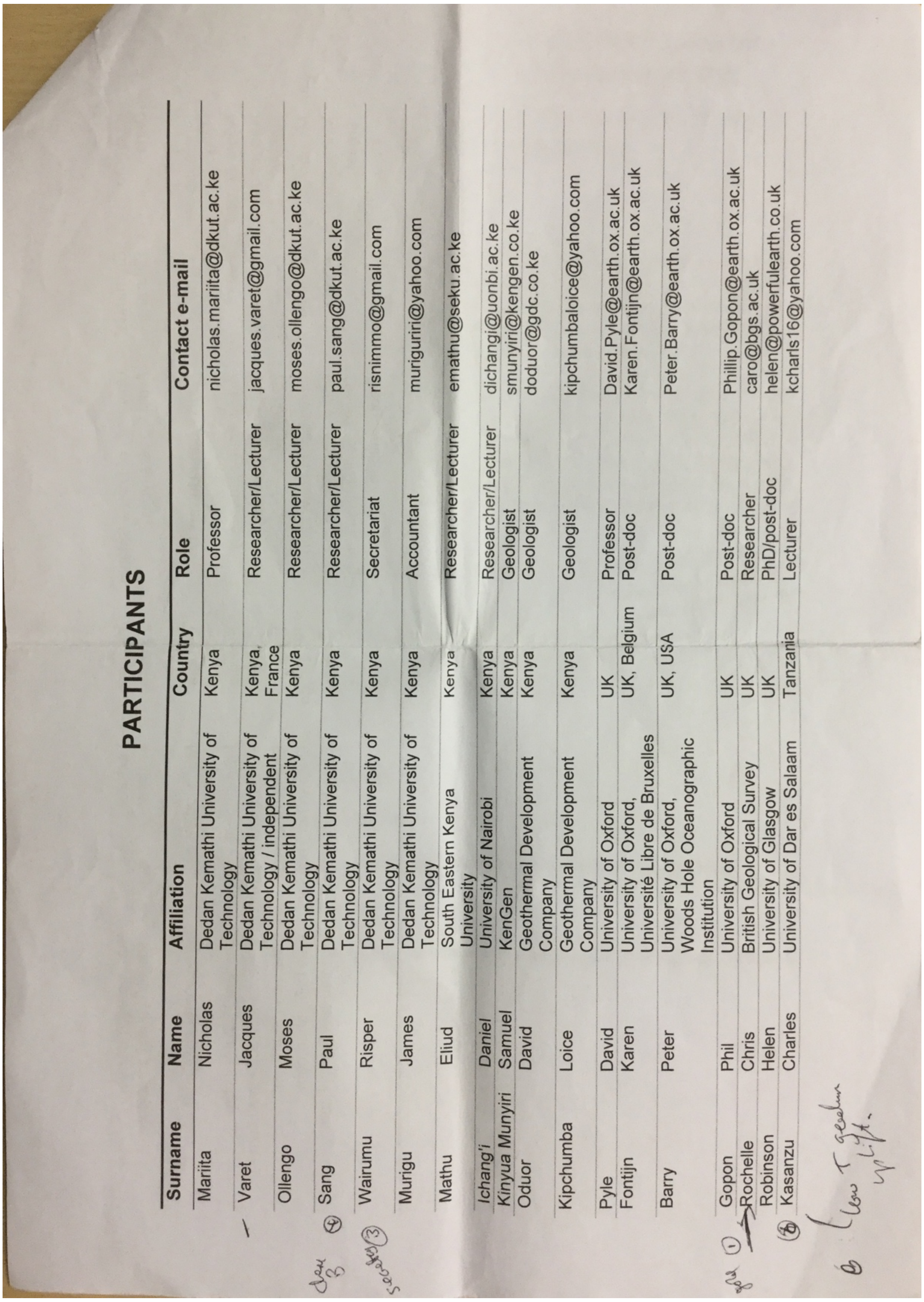
15:00 Tour of Ol Njorowa Gorge / Hells Gate National Park

17:00 Departure

Most international participants will head back to Nairobi for a late evening or early morning flight. Those flying out on Friday will be accommodated at ACK Guest House.

Appendix 2

List of participants.



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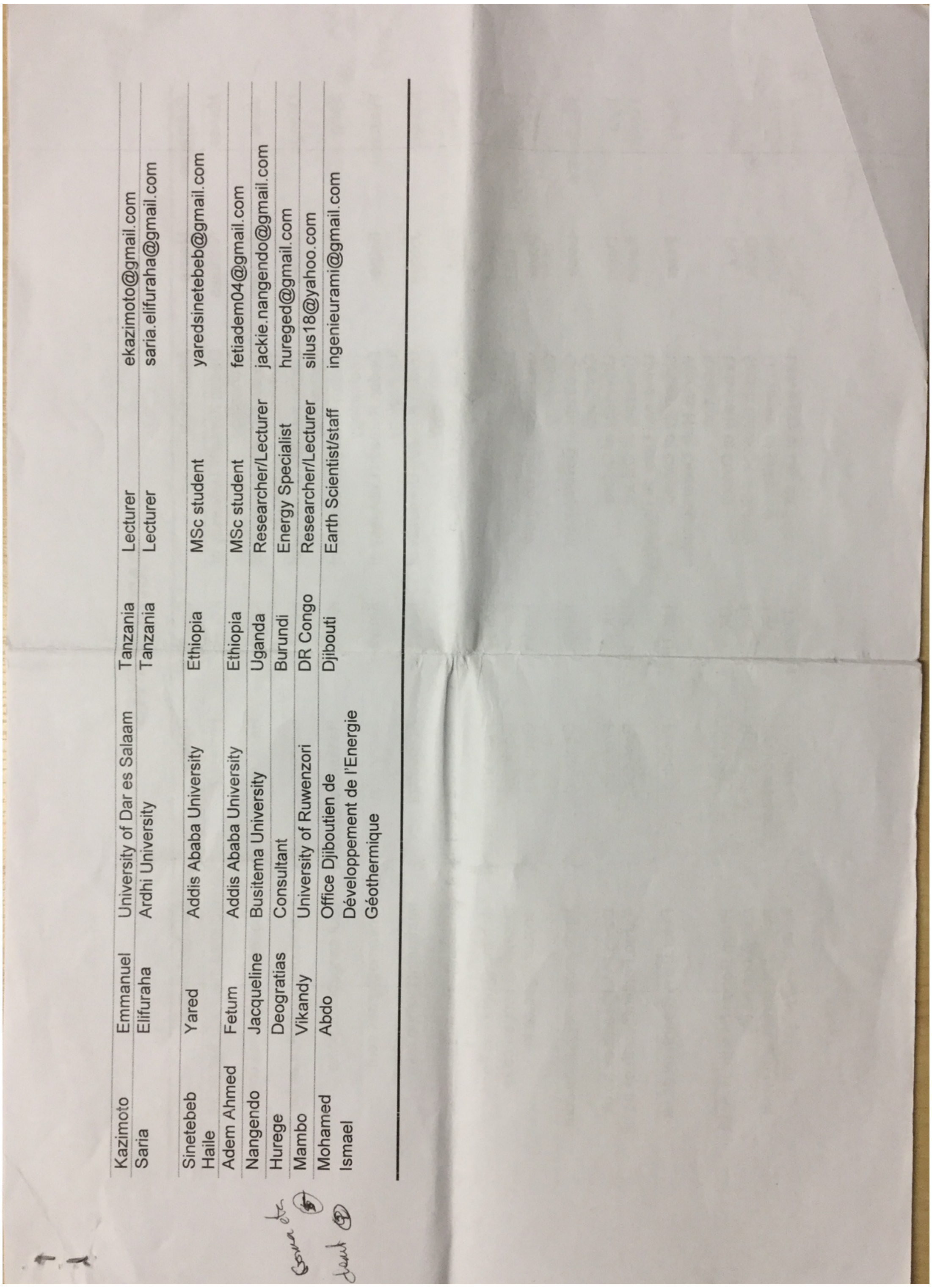
List of participants continued.



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