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Assessment of courses in ore microscopy and gold metallogeny.

NGU
Norges geologiske undersøkelse
Geological Survey of Norway
Geological Survey of Norway
N-7491 Trondheim, Norway
Tel.: 47 73 90 40 11
Telefax 47 73 92 16 20

REPORT

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Assessment of courses in ore microscopy and gold metallogeny.

Authors:
Nigel Cook and Peter M. Ihlen

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Summary:

Two training courses were held which aimed to increase the level of skills in ore geology and ore mineralogy among staff members at EIGS. The courses were intended to have relevance for on-going exploration and research activities within the ETHINOR program. Two separate 5 days courses were offered.

In order to improve future courses in geology given by NGU within the ETHINOR programme, we have been asked to give an evaluation of the course. This is based on our own impressions from the two weeks of courses and also the field trip to Lega Dembi, held between the courses. Our impressions from discussions with the participants are also noted. This evaluation is therefore somewhat subjective.

The course on ore mineralogy was aimed at the right level for the group. Certain introductory parts may, in fact, have been aimed at too low a level, since no previous knowledge was assumed. In contrast, parts of the course on gold metallogeny, especially the different ore forming processes, may have been too advanced and too theoretical for a large part of the audience. However, it seems that the majority of the course participants received enough basic knowledge in both courses to get the courage to attack the vast amount of literature on gold deposits and their mineralogy. In doing so, it is hoped that they will be able to understand and apply published data both on scientific and on exploration problems. A positive indication of this was apparent during the field trip to Lega Dembi, in which a number of participants were avidly discussing aspects covered in the courses and putting forward their own suggestions.

A number of recommendations have been included in this report. Most of these should be considered in conjunction with any possible continuation of the ETHINOR program.

Keywords: Ethiopia	Training course	Ore mineralogy
Gold	Metallogeny	□
□	□	□

CONTENTS

APPENDICES

ASSESSMENT OF TRAINING COURSES IN ORE MINERALOGY WITH SPECIAL EMPHASIS ON GOLD DEPOSITS AND METALLOGENY RELATED TO OROGENIC BELTS - POTENTIAL TYPES OF ECONOMIC GOLD DEPOSITS IN ETHIOPIA.

1. Introduction

Two training courses were held which aimed to increase the level of skills in ore geology and ore mineralogy among staff members at EIGS (and other geological institutions in Addis Ababa). The courses were intended to have relevance for on-going exploration and research activities within the Ethionor program. Two separate 5 days courses were offered.

The first course, "**ORE MINERALOGY WITH SPECIAL EMPHASIS ON GOLD DEPOSITS**" given by Nigel J. Cook introduced reflected light microscopy to EIGS staff members and provided practical experience with the mineralogy of opaque minerals. Special attention was given to different types of gold ores and the minerals found within them and to textural analysis of polished sections. The course was designed to enable EIGS staff to integrate reflected light micsroscopy into routine investigations of gold deposits. The course was held between 22nd and 26th November 1999. 21 participants (all from EIGS) took the course. All of these passed the examination on the final day and received certificates.

The second course, "**GOLD METALLOGENY RELATED TO OROGENIC BELTS - POTENTIAL TYPES OF ECONOMIC GOLD DEPOSITS IN ETHIOPIA**" given by Peter M. Ihlen was primarily intended to increase the knowledge among the EIGS staff members about gold forming processes. The course also addressed the commonly accepted gold deposit models, with special attention to those applicable to the Pan-African belt in western Ethiopia. Furthermore, the course was designed to increase familiarity with different exploration techniques and the practical use of ore deposit models in defining exploration targets. This course was held at EIGS in the period 6th to 10th December 1999. 24 participants from the mineral resources group followed the course and all passed the final examination and received their course certificates (see Appendix 1).

In order to improve future courses in geology given by NGU within the Ethionor programme, we have been asked to give an evaluation of the course. This is based on our own impressions from the two weeks of courses and also the field trip to Lega Dembi (28th November to 3rd December), held between the courses. Our impressions from discussions with the participants are also noted. This evaluation is naturally very subjective.

1.1. Aim of the courses

The aim of the course in ore mineralogy was to introduce the reflected light microscope to a group of EIGS staff who would have an interest in applying such techniques in their investigations. The course introduced a number of the more common minerals in a variety of ore types and allowed examination of different types of gold ores. The course combined lectures with practical classes. During the latter, participants worked in four groups on a selection of some 150 polished sections.

The aim of the course in gold metallogeny was to give an overview of major types of economic gold deposits occurring in Neoproterozoic and Phanerozoic orogens. Secondly, the aim was to show how these conceptual models could be applied to Ethiopia with emphasis on the Pan-African belt. The course participants could thereby use their own field observations to make deductions about potential gold deposits.

1.2 Course contents

The two courses were designed to integrate with one another. Neverthesss, the specific intersts of the course leaders led to some differences in focus. Also, it was inevitable that certain subjects were treated in both courses.

1.2.1 Ore mineralogy course

The course assumed no previous knowledge of ore mineralogy. For this reason, the course commenced from basic levels, explaining the importance of ore mineralogy and studies in reflected light in any investigation of ore deposits. Although gold deposits (both prime gold gold and by-product gold) featured prominantly throughout the course, the participants were also introduced to a variety of ore types, ranging from vein ores, massive sulphides, liquid magmatic and sedimentary ore types). Lectures dealt with aspects of ore mineralogy deemed relevant to the participants. Lectures were accompanied by a number of slide presentations (ca. 200 slides). The participants also had the opportunity to see polished sections representative of different types of ore deposit, inclding 'classic' deposits from around the world. Gold deposits were represented by Archean lode ores (sulphide and non-sulphide) from Noranda Greenstone belt, Canada. Gold tellurides from Bidjovaage, Norway and Mayflower, Wyoming, USA. Special attention was given to the occurrence of gold in massive sulphide ores (material from VMS and SEDEX deposits in Norway, Romania and Namibia was used). In addition, participants had the opportunity to examine material from many classic ore districts in the world – liquid magmatic deposits, volcanogenic deposits, sedimentary deposits etc. (e.g. Norilsk, Sudbury, Iberian Pyrite Belt, Sullivan, Rammelsberg. Polish Kupferschiefer, Banat skarn ores, Bergslagen, Kiruna) Emphasis was placed upon ore textures and typical mineral associations. The sample collection (ca. 150 specimens) used in the course are the personal teaching collection of the course leader. They contain some 120 ore minerals, including the ca. 40 most common ore minerals. These were introduced to the participants and their identification was encouraged).

Topics covered in the course were:

- General principles of ore mineralogy (introductory).
- Introduction to the reflected light microscope and -optics.
- The reflected light microscope and the properties of ore minerals used
- The preparation laboratory and preparation of samples for study in reflected light.
- The main types of ore deposits and their ore mineralogy and mineral associations (general background)
- Identification of the common sulphide and oxide minerals using the reflected light microscope.
- The mineralogy of gold (discussion of the most common gold-bearing minerals).
- Microscopy of gold-bearing ores from different types of deposits (sulphide ores, vein ores, telluride-rich ores etc).
- The mineralogical distribution of gold in different deposit types.

- Microscopic analysis of textures among ore minerals.
- What is "invisible gold" and how can it be quantified?
- Advanced ore mineralogy – use of microanalysis and other techniques.
- Calculation of mineralogical balances for gold (and other metals).
- Gold mineralogy and its implications for ore processing.
- Open discussion on the use of reflected light microscopy in routine studies in Ethiopia, with examples as necessary, additional opportunity for practise on the microscope, with time for question/answer session and further discussions.

Each participant received course material in the form of loose-leaf handouts at the beginning of each session. Input from course participants was encouraged throughout the course so that the course evolved such as to meet the immediate needs of the participants.

The final day of the course reviewed themes discussed previously during the week. The course was terminated by an examination, in which each participant was asked to look at a polished section and then comment on it in front of the class. Each participant received a certificate detailing their achievement.

Comments:

The course participants came to the course with some polished sections from Ethiopian gold and base metal occurrences. This enabled them to see Ethiopian gold and participate in discussions about genetic type etc.. However, the polishing quality of much of their sample material was poor and it was not possible to integrate these sections properly into the course. An assessment should be made of the preparation laboratory at EIGS in respect to the preparation of polished specimens.

Discussion during the course brought forth that most EIGS staff required training in some basic concepts pertaining to the preparation of material for study. For example how to mark a sample for preparation and polishing, how to circumvent the nugget effect in investigations of gold deposits and how to estimate size of grains under the microscope

1.2.2 Gold metallogeny course

The course was separated into two sessions. Each day started with a session where the participants were introduced to important aspects of gold metallogeny. Topics related to crustal accretion including the terrane concept, types of fluids in the crust, source rocks, fluid-rock interaction, effective precipitation mechanisms for gold and different types of conceptual models for the formation of major pre-, syn- and post-orogenic gold deposits. The afternoon sessions comprised group work (the class was divided into 5 groups). The groups discussed aspects of gold metallogeny relevant for prospecting in Ethiopia. In addition, each day, one member of the EIGS staff presented different aspects of Ethiopian geology and metallogeny as an introduction to later group work. The final programme for the course is given in Appendix 2. Conceptual models for the following types of gold deposits were given in the following lectures:

- Shear-hosted Au deposits with special reference to plutonic terranes (Late-orogenic).
- Turbidite-hosted Au deposits (Syn- to late-orogenic)
- Ironstone-hosted Au-Cu-(Bi) deposits associated with granite magmatism along shear zones, Tennant Creek or Glenorchy type deposits (Syn-orogenic).

- Porphyry Cu-Au deposits (Pre-orogenic)
- Intrusive breccia/breccia pipe Au deposits (Pre- and post-orogenic)
- Skarn Au deposits (Pre- to post-orogenic)
- Auriferous massive sulphide deposits (Pre-orogenic)
- Epithermal Au deposits, including kaolinite-alunite and adularia-sericite sub-types (Pre-orogenic)
- Carlin-type sediment-hosted Au deposits (Post-orogenic)

The final day of the course focused on prospecting methods commonly used in gold exploration and on the requirements from the mining industry to invest in follow-up work on mineralisation found by EIGS. The course was terminated by a short examination of the individual participants.

2. Organisation of the courses

Despite the fact that there were some minor delays in preparing the lecture room for the course, it was possible to conduct the courses closely following the proposed programmes. The course leaders should have given clearer instructions prior to the start of the course. For example, it was proved incorrect to assume that the teaching room would 'automatically' have a blackboard installed and that a slide projector would be readily available. These matters were corrected with only minor delays and the willingness of EIGS staff to carry out these jobs must be complemented.

2.1 Ore mineralogy course

The course was designed to give a wealth of information to the participants in a short intensive period. For this reason, some topics were dealt with only very briefly. Emphasis was placed on the occurrence of ore minerals, characteristic assemblages and on the economic implications of ore deposits – and where possible, to types of deposits which the participants themselves were likely to encounter. Repeated reference was given to such topics as ore grade, nugget effects in sampling, the importance of refractory gold in some deposits, and above all, the implications which mineralogy has on ore processing. Where possible, participants received handouts. Each participant also received copies of two publications reviewing gold mineralogy (there is no single adequate textbook available). A set of 10 publications of the course leader dealing with different aspects of ore mineralogy and a selection of overheads used during the course were left for further copying (Appendix 3).

Comments:

It was a pity that all four microscopes were not available at the outset of the course and that some time was lost in collecting microscopes, setting them up, as well as other tasks (slide projector, putting up curtains).

The photocopying of large amounts of handouts at EIGS proved difficult. This is not the fault of EIGS, with limited human resources in this area and few copiers. Rather, it underlines the urgent need for the project manager to have a small fund avaialable so that these kind of 'problems' can be solved outside EIGS (e.g. by sending all necessary handouts to a copy-service in town). The lack of such a small contingency fund hampers efficient carrying out of the ETHINOR project)

2.2 Gold metallogeny course

The present author was responsible for the accomplishment of the course program and giving review lectures about gold metallogeny related to orogenic belts. Secondly, background material was given to each of the participant. These photocopied handouts covered gold metallogeny in general as well as individual types of deposits. The volume of material comprised 14 articles @ ca. 20 pages each and was given to each participant (Appendix 4). A set of about 10 other articles and a selection of overheads used during the course were left for further copying.

EIGS was responsible for copying the background material (around 5000 pages in total) and for preparation of coffee and mineral water for the course leader and the participants during the breaks. EIGS was also responsible for choosing staff members willing to talk about different aspects of gold metallogeny and prospecting as well as about the terrane concept applied to the Pan-African belt of Ethiopia.

Comments:

It took 2 weeks to copy the articles. These were delivered bit by bit to the participants. They did not receive a full set of copies before the final day of the course. It had been the intention to use these during the course, not least as an aid for those that had difficulties understanding the conceptual models that were presented. The copying was not well organised and not worthy of a organisation like EIGS.

Too much time was used for the coffee breaks - which generally lasted for 45, rather than the stipulated 30 minutes, which would have been possible if the coffee had been brought to the lecture room. This meant that a total of 2 hours was lost on walking to the nearest coffee shop on the Asmara road and back. In addition, the course leader had to personally organise the mineral water used during the lecture sessions. These unnecessary and time consuming activities resulted in the deletion of the course section on unconformity-related U-Au deposits. I hope therefore, that these things can be improved prior to the next course.

EIGS had selected the right staff members for the presentations of Ethiopian geology and Masresha G.Selassie, Tarekgne Tadesse, Tadesse Workhu and Wubshet Zewdie delivered excellent and clarifying lectures. I am very grateful for their contributions to the course and for their organisational assistance. Especially, I would like to thank Masresha G.Selassie and Tadesse Workhu.

3. Evaluation of the participants

3.1 Ore mineralogy course

The participants were enthusiastic during all five days of the course. Generally, the participants would stay in the lecture room during coffee breaks and lunch hours and use the time to study the polished sections.

There was naturally, some difference in abilities. Some participants had some limited experience from before (the three who has studied I the former USSR) and were keen to brush up their knowledge. The level of questions asked during, and at the end of the lectures, was in general good and showed that they had comprehended the information given and, furthermore, were able to think about how this might be applied. It proved a good idea to conduct the lectures in short bursts, allowing maximum use of the time when the attention span was at its highest.

The thirst for knowledge was very marked and all participants were hungry for additional information, not originally intended for presentation. For example, they devoured a brief impromptu lecture on the mineralogy of skarn deposits.

It was clear, however, that most participants lacked experience of visiting different types of mineral deposits, and that visits to active mining operations provide the type of knowledge required. Time and time again, the discussion returned to issues of grade and tonnages of mineable deposits and how mineralogical study of polished sections is but a part of the issue. A course on the economics of mineral deposits would, in my mind, be a very welcome addition to the trainee programme at a future date.

3.2 Gold metallogeny course

All participants were active and enthusiastic during the last four days of the course. They had many questions to the present author during his presentations. However, during the first day they were very quiet, probably due to their Ethiopian cultural background where authorities and superiors are treated with much respect.

Although the course participants had B.Sc. and M.Sc.university degrees, it became apparent through the group-work sessions and the final short examination, that the audience roughly could be subdivided into two groups. One group comprise the staff members working mainly with pure prospecting including different types of geochemical sampling and trenching. This group had seemingly forgotten much of what they learned in university since they had not actively been using this knowledge. They also had a poor knowledge about geological processes and terminology in general and some did not even know the composition of the common rock-forming minerals, for example that mica is not a feldspar. The second group represented staff members, whom mainly work with geological problems during exploration work, such as semi-regional to deposit-scale bedrock mapping and logging of trenches and drill cores. This group comprised members with a good to very good geological knowledge.

Only a few of the participants have had the opportunity to visit a gold mine, e.g. the Lega Dembi mine, and realised the dimensions of economic deposits and what is needed to get mining companies interested to invest money into any mineralisation found by EIGS. We are talking about several hundred thousand cubic metres of rock containing on an average several

tens of grams of gold per cubic metres. The participants who have not visited a productive gold mine, will never really grasp this point from lectures, namely that we are searching for large volumes of mineralised rock and not a single quartz vein.

Comments:

If EIGS have the intention to upgrade the staff members with poor geological knowledge, emphasis must be made on rather elementary courses in petrology and structural geology. To some extent, this can also be done by investing in modern textbooks on ore formation, gold metallogeny, magmatic and metamorphic petrology and geothermal systems. If this is not the intention, it would be better to let these staff specialise in prospecting techniques instead.

Those who are working as exploration geologists should get the opportunity to travel abroad and visit economic gold deposits relevant for Ethiopia. The best collection of orogen-related gold deposits are found distributed along the Lachlan Fold Belt in eastern Australia and along the island arcs around Papua New Guinea or in the Cordilleras and Rocky Mountains of western Canada and USA, respectively. The majority of the people selected for such a tour should be staff members, whom are actively dealing with geological problems in the field. It is also important that some of the junior members of the staff take part and get the opportunity to be upgraded. It is critical to invest in the junior members of staff, since they wil,l to a large degree, represent the basis for EIGS future development.

4. Evaluation of the group work

4.1 ore mineralogy course

Four microscopes were available in the lecture room, with ca. 4-6 students per microscope. However, they were encouraged to visit the other groups to exchange observations. At any given time, ca. 10 polished sections were in circulation. Every so often, the course leader interrupted the class to emphasise one point or another. Most participants worked well in the groups, showed good powers of observance and ability to make concise notes on the sample material. I moved around from group to group answering questions, confirming mineral identifications and drawing attention to interesting assemblages and textures. In this, I was assisted by Cristiana Ciobanu who had accompanied me to Addis. Her assistance during the group work proved of great value, given the enthusiasm and interest of the participants in the sections. Throughout the course, attention was given to the difficulties of mineral identification in different assemblages – returning to the same common minerals in different associations.

By the end of the course, most participants had seen ca. 130 polished sections and were able to recognise, in most cases, the more common oxide and sulphide minerals. In addition, they were able to use tables of diagnostic properties to predict the identification of the more unusual minerals in the sections.

The examination on the final day proved a worthwhile exercise. Each participant was asked to look at a polished section and report on its mineralogy, texture and possible genesis in front of the class. Neither the participants nor the course leader had seen these sections prior to this (the sections, various ores from the Røros area, had arrived from the NGU-lab on the day of departure to Addis). I was impressed by their ability to recognise the common sulphide

minerals and for their insightful comments on ore textures and the identity of trace components.

4.2 Gold metallogeny course

The different groups worked well when the problems presented to them were well explained. The individual members used there own skills and imagination to transfer the different types of conceptual gold deposit models to the geological environments prevailing in Ethiopia. The presentations by the group leaders lead to the following conclusions:

- The main metallic resource of Ethiopia is undoubtedly gold. Iron and base-metals resources are presently found to be of minor importance. Therefore, EIGS should keep their focus on gold exploration (while at the same time being aware of other types of mineralisation).
- Laterite (eluvial) and alluvial gold deposits occur widespread within the Pan-African terranes and a number of these deposits have a beltiform distribution along the major suture zones. Since the presence of eluvial and alluvial gold deposits show where hard-rock gold mineralisation occur, as in Ethiopia, their location should be made readily accessible through a database. The distribution of alluvial gold deposits will indirectly point to areas hosting potentially economic gold mineralisation. The construction of such a database should have a high priority as well as registering the hard-rock gold.
- Shear-hosted Au deposits associated with subsidiary structures along major terrane boundaries appear, at present, to be the best exploration target.
- There also exist indications that ironstone-hosted Au-Cu, skarn Au, and deformed epithermal Au deposits may occur inside the Pan-African belt of Ethiopia.

Comments:

There exist remarkably few published descriptions of Ethiopian ore deposits and in particular gold deposits. In order to promote gold prospecting, in Ethiopia it is critical to make such information available for the World community. Staff members should, therefore, be encouraged to write publications about different aspects of gold metallogeny in Ethiopia. Ideally, such contributions should be published in international journals.

Potential areas for future gold exploration are calderas and maar volcanoes (sinter cones) within the East-African rift. There already exist data indicating that some of the Quaternary and Tertiary geothermal systems related to acid volcanism contain anomalous gold concentrations. No major investigations of such systems have so far been conducted and should be assessed.

Tadesse Workhu and Wubshet Zewude presented from the Moyala and Baruda areas, respectively, examples of vein mineralisation affected by lateritisation. In the Moyale area, gold-rich pieces of quartz with visible gold are found as float above a trenched quartz vein. However, analyses of numerous drill cores from the vein yield only background values. The same is also the case for the quartz breccia at Barruda where crushing and panning of quartz samples yield several gold grains, per every fourth or fifth sample. In contrast analyses of samples from the trenches return averages generally in the range of 0.1-0.2 ppm Au per metre. Although these two phenomena can be explained in terms of gold mobilisation above the groundwater table and applied sampling techniques, respectively, research on the behaviour of gold during deep weathering and lateritisation is needed, especially in

conjunction with forthcoming drilling programs. Drill holes should not intersect the mineralised zone above the normal groundwater level.

It appears from the Baruda case history that the amount of analysed rock samples is 5-10 times lower than normally acquired by western mining companies in defining potential gold-rich zones for follow-up work. The presence of visible gold in crushed sample of the breccia is insufficient information for any investors to assess the economic potential of the mineralisation. What they ask for is analytical gold grades and dimensions. Therefore, trenches should be tested in a systematic manner by dense chip sampling or channel sampling. Samples should not be collected without being immediately analysed at a high-quality laboratory abroad. This includes the soil samples from the Baruda breccia zone which have to be analysed before assessing a drill program.

5. Evaluation of course leadership

5.1 Evaluation of own presentation (Cook)

In keeping with the workshop character of the course, each day contained a number of different elements, short (30-45 minute) lectures, group-work on the microscopes, free discussion and slide presentations). This method of presentation, meaning that a large number of different themes were examined each day was meant to keep the group involved and to keep motivation at a high level.

I selected to show ca. 200 colour slides, showing various types of ore textures. Despite a poor slide projector and insufficient window blinds, this was well-received and allowed all participants to see a range of ore minerals and textures not included in the sample suite brought to Addis.

The levels of interest displayed by the participants were overwhelming, and in fact covered more ground than I had expected to given their thirst for knowledge.

I realise that it would have been advantageous to bring more literature with me – and, in particular, more copies of relevant overheads. I had transported a dozen different textbooks on ore geology and ore mineralogy and these were permanently in use by participants, being returned well-thumbed!

It could have been of advantage to been in possession of more material from Ethiopian occurrences available for study. Should the quality of sample preparation be brought up to the required standard, EIGS should attempt to set up a reference collection of suitable polished sections.

5.2 Evaluation of own presentation (Ihlen)

The lectures were based on overheads and use of a «black-board». This type of presentation may in the long run become somewhat dull and boring and for many participants, very theoretical. Far better would be to use a collection of samples of different types of auriferous ores coupled with slides showing the real situation in nature – thus making the course more of a workshop and encouraging active participation and discussion throughout the course. Unfortunately, the present author forgot to bring his own collection of slides from NGU

during a hasty departure from Trondheim. However, the lecture room was not well suited for showing slides, since few windows have blinds.

The presentations were aiming at an audience holding a B.Sc. level. However, it became soon apparent that the geological knowledge ranged from undergraduate level to M.Sc. level, according to European university standards. Therefore, the present author feels that the course was a bit too advanced for many in the audience. Nevertheless, the participants seemed to be very pleased with my effort to teach them the main principals of gold metallogeny in relation to orogenic belts and opening their eyes for other types of potential gold deposits, than the shear-hosted.

Through the final examination it became clear that I had managed to transfer to them some important principles related to gold metallogeny, for instance:

- How to recognise in the field indications of former migration of hydrothermal fluids trough the crust.
- The controls the mineralogy of any hydrothermal alteration.
- The trilateral relationships between gold, fluids (veins/alteration) and sulphides.
- Field relationships characterising the major types of orogen-hosted gold deposits.
- Field relationships characterising different types of breccias.

Comments:

It is recommended that EIGS invest in a lecture room equipped with blinds, proper blackboard and two screens for simultaneous use of slide and overhead projectors. This will cover the needs for forthcoming courses, workshops and lectures at EIGS within the ETHINOR program. A good slide projector, would be an excellent investment for future courses.

6. Conclusions and recommendations

The course on ore mineralogy was aimed at the right level for the group. Certain introductory parts may, in fact, have been aimed at too low a level, since no previous knowledge was assumed. This is, however, not regarded as negative, since repetition of the basic principles underlying ore microscopy was seen as of advantage by those who already had some previous experience from their university days.

In contrast, parts of the course on gold metallogeny, especially the different ore forming processes, may have been too advanced and theoretical for a large part of the audience. In addition, the present author's performance may have been better with the aid of slides and ore samples.

However, it seems that the majority of the course participants received enough basic knowledge in both courses to get the courage to attack the vast amount of literature on gold deposits and their mineralogy. In doing so, it is hoped that they will be able to understand and apply published data both on scientific and on exploration problems. A positive indication of this was apparent during the field trip to Lega Dembi, in which a number of participants were avidly discussing aspects covered in the courses and putting forward their own suggestions. The courses certainly gave the participants the courage to open up and be prepared to discuss

and contribute and also to see that so called 'experts' who led the courses do not always know all the answers.

A number of recommendations have been included as comments above. Most of these should be considered in conjunction with any possible continuation of the Ethionor program. The most important recommendations are repeated below:

- The upgrading of staff members in geology and prospecting should be continued through M.Sc. programs and courses in structural geology and magmatic and metamorphic petrology. The aim of the trainee programs is to make the advisors redundant.
- Investment in a permanent lecture room equipped with blinds, blackboard, slide projector and two screens for simultaneous use of slide and overhead projectors.
- Modern textbooks about ore genesis, ore mineralogy, gold metallogeny, magmatic petrology, prospecting techniques etc. should be purchased in order to encourage the staff members to make further developments of their own skills in geology and geoscience. These books (Appendix 5) should be more readily available to potential borrowers than is the case with resources in the EIGS library at present.
- Preparation of polished ore samples is clearly still a problem at EIGS. Participants can only use the skills they have learnt if the laboratory is equipped, and the staff responsible are adequately trained, to produce polished sections of the required quality. It is of little use to possess research microscopes if the laboratory staff are ill-equipped or too inexperienced to produce sample material for investigation. EIGS staff members must look into this.
- Encourage the staff members to write publications in order to increase the knowledge about Ethiopian ore deposits and in particular the gold occurrences among the World communities, and thus promote further prospecting activity in Ethiopia. At the very least, a general review of Ethiopian ore deposits should be produced, showing locations of known deposits and referencing reports/publications. This could form the basis for a brochure-type publication designed with international mining companies and potential investors in mind.
- Invest in ore database work and registration of hard rock and alluvial/eluvial gold occurrences in Ethiopia. This is important both for scientific research and exploration.
- Invest in travel abroad to productive gold deposits or mines. Staff members actively working in the field with geological problems should be selected for such tours together with some of the junior members of the staff.
- Core drilling in the Baruda-Egambo area should not be carried out before all soil samples and rock samples have been analysed in a high-quality laboratory, preferably overseas. A full assessment of the different data sets has to be made before positioning the drill holes. Remember that a drill hole barren in gold will kill the project.

APPENDIX 1 List of workshop participants

1. WORKSHOP PARTICIPANTS IN GOLD METALLOGENY ONLY

1. Abera Fantye
2. Adugna Debele
3. Masresha G.Selassie
4. Melkamu Mengstie
5. Melese Getahun
6. Sisay Libasse
7. Tadesse Faji
8. Tsegaye Talila
9. Demerew Yirgu

2. WORKSHOP PARTICIPANTS IN ORE MICROSCOPY AND GOLD METALLOGENY

1. Ghilamichael K.Mariam
2. Ibrahim Yusuf
3. Yismaw Ewunetie
4. Ayele Wondimu
5. Tesfaye Selato
6. Solomon Kejella

3. WORKSHOP PARTICIPANTS IN ORE MICROSCOPY ONLY

1. Mesfin Tesema
2. Addise Mekonne
3. Girma Asemu
4. Kassahun Berhan
5. Yenenesh Abebe

4. WORKSHOP PARTICIPANTS IN ORE MICROSCOPY, GOLD METALLOGENY AND FIELD EXCURSION TO LEGEDEMBI

1. Tadesse Worku
2. Melese Miteku
3. Habtamu Kassahun
4. Tewolde berhane Abay
5. Wubshet Zawude
6. Teshome Numero
7. Tedbabu Worku
8. Amha Haileyesus
9. Tekaligne Tesfaye
10. Abraham Kidanu

APPENDIX 2 Course in gold metallogeny

- Lecture on the formation of gold deposits in volcanic terrains with emphasis on epithermal deposits
- Group work and open discussions on the possibilities in Ethiopia.
- Lecture on hydrothermal fluids and alteration associated with gold deposition.

- Lecture on the formation of gold deposits in plutonic terrains with emphasis on granite-related deposits.
- Group work and open discussions on the possibilities in the Pan-African belt.
- Lecture and discussion on the behaviour of gold during lateritisation and its effect on the choice of exploration techniques for gold in the tropical environment.

- Lecture on the formation of gold deposits in metamorphic terrains with emphasis on shear-zone and turbidite-hosted deposits.
- Group work and open discussion on the possibilities in western Ethiopia.
- Lecture and discussion on different types of exploration techniques used during regional and follow-up work. What type of data are wanted by the industry?

- Lecture on unconformity-related auriferous deposits with emphasis on Olympic Dam type deposits.
- Group work and discussions on the possibilities in Ethiopia.
- Lecture on the use of microscopy, isotope, fluid inclusion and lithochemical techniques in gold prospecting.

- Lecture summarising the major gold deposit models.
- Discussion on the possibilities for economic gold deposits in Ethiopia.
- Lecture summarising the most efficient exploration techniques for gold.

APPENDIX 3 Articles distributed during the ore mineralogy workshop

Boyle, R.W. (1979): The Geochemistry of Gold and its Deposits Geol. Surv. Canada Bull, no. 210. (selected parts)

Cook, N.J. (1990): Mineralogical examination of gold-bearing samples. CIM Bulletin, December 1990, 51-55.

Gasparrini, C. (1983): The mineralogy of gold and its significance in metal extraction. CIM Bulletin, March 1983, 144-153.

Gasparrini, C. (1984): The mineralogy of silver and its significance in metal extraction. CIM Bulletin, 99-110.

Spry, P.G. & Gedlinske, B.L. (1987): Tables for the Determination of Common Opaque Minerals. Economic Geology Publishing Co., 52 pp..(USD 10.00) (selected parts)

Together with copies of own notes and figures from various books and publications

Also the following publications of the course leader were made available in connection with specimens investigated during the course:

Cook, N.J., and Chryssoulis, S.L. (1990): Concentrations of "invisible gold" in the common sulphides. Canadian Mineralogist, 28, 1-16.

Cook, N.J. (1992): Antimony-rich mineral parageneses and their association with Au minerals within massive sulphide deposits at Sulitjelma, Norway. Neues Jb. für Mineralogie Mh. Jg. 1992, Heft 3, 97-106.

Cook, N.J., Halls, C., and Boyle, A.P. (1993): Deformation and metamorphism of massive sulphides at Sulitjelma, Norway. Mineralogical Magazine, 57, 67-81.

Cook, N.J., Klemd, R., and Okrusch, M. (1994): Sulphide mineralogy, metamorphism and deformation in the Matchless massive sulphide deposit, Namibia. Mineralium Deposita, 29, 1-15.

Cook, N.J., and Wood, S.A. (1994): Platinum-group minerals in the Lac Sheen Cu-Ni-PGE prospect, Quebec. Canadian Mineralogist, 32, 703-712.

Cook, N.J., Wood, S.A., Gebert, W., Bernhardt, H.-J., and Medenbach, O. (1994): Crerarite,a new Pt-Bi-Pb-S mineral from the Cu-Ni-PGE deposit at Lac Sheen, Abitibi-Temiscaminque, Quebec, Canada. Neues Jahrbuch für Mineralogie Monatsheft, Jg. 1994, Heft 12, 567-575.

Cook, N.J. (1996): Ore mineralogy and remobilisation phenomena in the Sulitjelma massive sulphide deposits, Northern Norway. Ore Geology Reviews, 11, 303-338..

Wagner, T., and Cook, N.J. (1996): Bismuth-antimony sulphosalts from the Apollo Mine, Siegerland, FRG. Neues Jahrbuch für Mineralogie Abh. 171, 135-153.

Cook, N.J. and Hoefs, J. (1997): Sulphur isotope charcteristics of metamorphosed volcanogenic massive sulphide deposits in the Norwegian Caledonides. Chemical Geology 135, 307-324.

Cook, N.J. (1997): Bismuth and bismuth-antimony sulphosalts from Neogene vein mineralisation, Baia Borsa area, Maramures, Romania. Mineralogical Magazine, 61, 387-409.

Wagner, T., and Cook, N.J. (1997): Mineral reactions in sulfidic systems as a marker of evolving fluid geochemistry - a case study from the Apollo Mine, Siegerland, Germany. Mineralogical Magazine, 61 , 573-590.

Cook, N.J., and Damian, Gh. (1997): New data on 'plumosite' and other sulphosalt minerals from the Herja hydrothermal vein deposit, Baia Mare district, Romania. Geologica Carpathica, 48, 387-399.

Cook, N.J. (1998): Bismuth sulphosalts from hydrothermal vein deposits of Neogene age, N.W. Romania. Mitt. Österreich. Mineral. Gesellsch., 143, 19-39.

Cook, N.J., Spry, P.G., and Vokes, F.M. (1998): Mineralogy, paragenesis and metamorphism of ores in the Bleikvassli Pb-Zn-(Cu) deposit, Nordland, Norway. Mineralium Deposita, 34, 35-56.

Wagner, T., and Cook, N.J. (1998): Sphalerite mobilization during multistage hydrothermal mineralization - examples from siderite Pb-Zn-Cu-Sb veins, Rheinisches Schiefergebirge, Germany. Mineralogy and Petrology, 63, no. 3-4 (Nov. 1998).

APPENDIX 4 Articles distributed during the gold metallogeny workshop

Bolger, C., and Cozens, G. (1993): A Comparison of Mineral Deposits at the Gecko and White Devil Deposits: Implications for Ore Genesis in the Tennant Creek District, Northern Territory, Australia, Econ. Geol., 88, 1198 - 1225

Bowell, R.J., Foster, R.P. and Gize, A.P. (1993): The Mobility of Gold in Tropical Rain Forest Soils Econ. Geol., 88, 999–1016.

Cox, S. F., Sun, S.-S., Etheridge, M. A., Wall V. J. and Potter, T. F. (1995): Structural and Geochemical Controls on the Development of Turbidite – Hosted Gold quartz Vein Deposits, Wattle Gully Mine, Central Victoria, Australia. Econ. Geol., 90, 1722–1746.

Davidson, G.I., and Gandhi, S.S. (1989): Unconformity-Related U-Au Mineralization in the Middle Proterozoic Thelon Sandstone, Boomerang Lake Prospect, Northwest Territories, Canada. Econ. Geol., 84, 143-157.

Grauberger, G. (1985): A Diatreme–Hosted Gold Deposit at Montana Tunnels, Montana. Econ. Geol., 80, 1707-1721.

Hodgson, C.T. (1989): The Structure of Shear-related, Vein-type Gold Deposits: a review. Ore Geol. Rev., 4, 231-273.

Jones, R. B. 1989: Carlin Trend Gold Belt: The Geology. Mining Magazine – October 1989, 256-261.

Jones, B.K. 1992: Application of metal zoning to gold exploration in porphyry copper systems. J. Geochem. Expl., 43, 127-155.

Klein, T.L. and Criss, R.E. (1988): An Oxygen Isotope and Geochemical Study of Meteoric-Hydrothermal Systems at Pilot Mountain and Selected Other Localities, Carolina Slate Belt. Econ. Geol., 83, 801-821.

Krupp, R.E. and Seward, T.M. (1987): The Rotokawa Geothermal System, New Zealand: an Active Epithermal Gold–Depositing Environment. Econ. Geol., 82, 1109-1129.

McMillan, W.J. and Panteleyev, A. (1986): Porphyry Copper Deposits *In*: Ore Deposit Models. Geoscience Canada Reprint Series 3, 21-30.

Meinert, L.D. (1998): Gold in Skarn deposits – a preliminary overview, Proceedings of the Seventh Quadrennial IAGOD Symposium, 363-374.

Nutt, C.J. (1989): Chloritization and Associated Alteration at the Jabiluka Unconformity-Type Uranium Deposit, Northern Territory, Australia. Can. Mineral., 27, 41-58.

Oreskes, N., and Einaudi, M.T. (1990): Origin of Rare Earth Element Enriched Hematite Breccias at the Olympic Dam Cu–U–Au-Ag Deposit, Roxby Deposit. Roxby Downs. South Australia: Econ. Geol., 85, 1-28.

Ramsay, W. R. H., Bierlein, F. P., Arne, D. C. and van den Berg, A.H.M. (1998): Turbidite – hosted gold deposits of Central Victoria, Australia: their regional setting, mineralising styles, and some genetic constraints. Ore Geol. Rev., 13, 131-151.

Romberger, S.B. 1986: Disseminated Gold Deposits. In: Ore Deposit Models. Geoscience Canada Reprint Series 3, 21-30.

White, N.C., Leake, M. J., McCaughey, S.N. and Parris, B.W. (1995): Epithermal gold deposits of the southwest pacific. J. Geochem. Expl., 54, 87–136.

APPENDIX 5 Textbooks recommended for puchase by EIGS

Craig, J.R. & Vaughan, D.T. (1994): Ore Mineralogy and Ore Petrography. 2nd edition, John Wiley & Sons, 434 pp..(ca. GBP 30.00)

Guilbert, J.M.& Park, C.F.Geology of Ore Deposits (Now out of print)

Picot, P. & Johan, Z. (1981): Atlas of Ore Minerals. Elsevier, 458 pp..(? out of print)

Spry, P.G. & Gedlinske, B.L. (1987): Tables for the Determination of Common Opaque Minerals. Economic Geology Publishing Co., 52 pp..(USD 10.00)

Barnes, H.L., ed. (1997): Geochemistry of Hydrothermal Ore Deposits. 3rd edition, John Wiley, 992 pp.. (Amazon Price USD 115)

Ixer, R.A. (1990): Atlas of Opaque and Ore Minerals in Their Associations. Open University Press, Milton Keynes, 208 pp.. Out of print but available directly from author at r.ixer@btinternet.com for GBP 75.00.

Roberts, R.G. & Sheahan, P.A. (1988): Ore Deposit Models Vol. I. Geoscience Canada Reprint Series, 3 (USD 48).

Sheahan, P.A. & Cherry, M.E. (1993): Ore Deposit Models Vol. II. Geoscience Canada Reprint Series, 6 (USD 48).

Journals

Economic Geology (USD 75 p.a. for individuals)
Mineralium Deposita (DEM 120 p.a. for individuals)