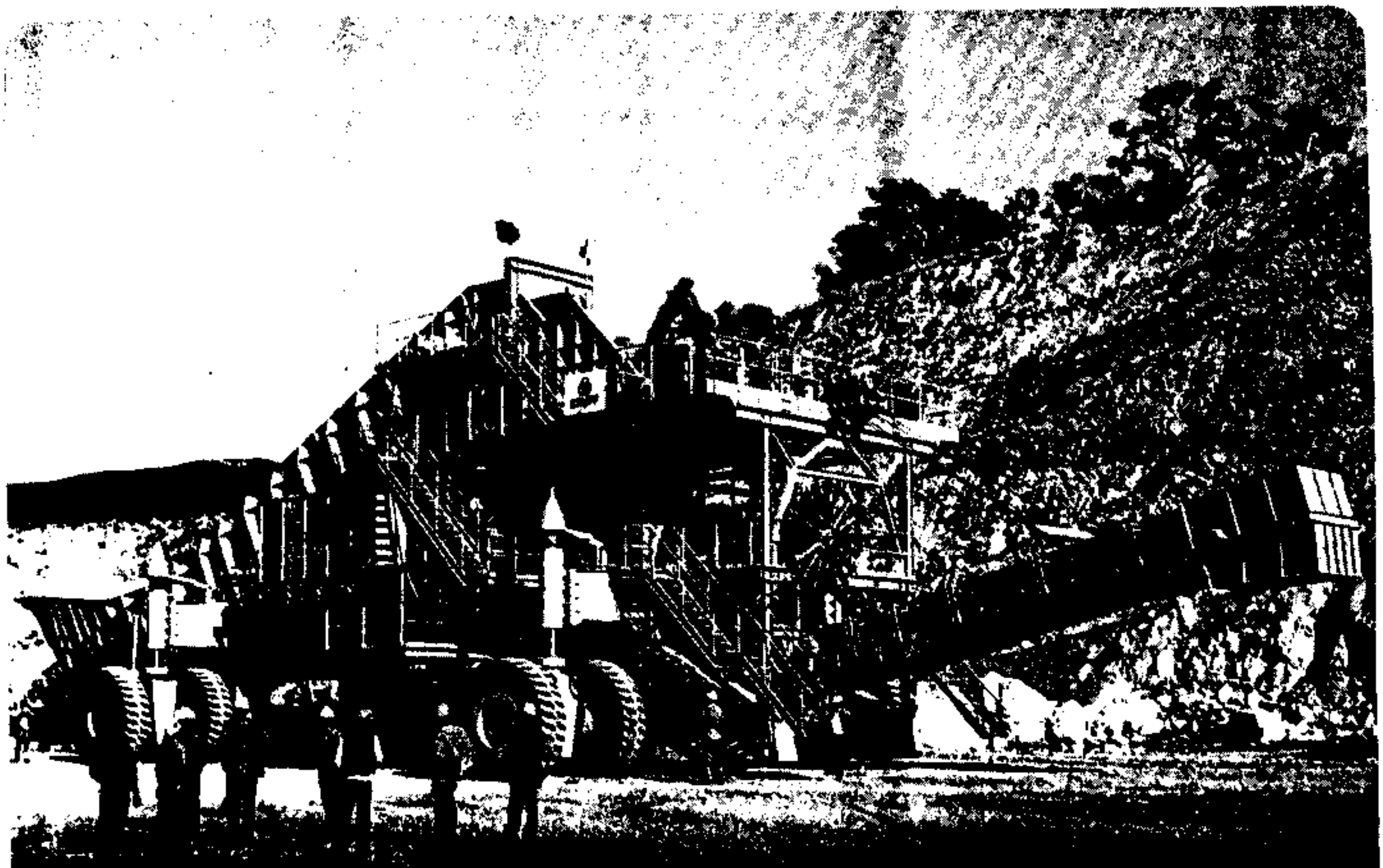
Journal of the Association of Teachers of Geology

GEOLOGY teaching

Volume 11, Number 1, March 1986



GEOLOGY THE WEALTH CREATING SCIENCE & EDUCATION

A FIELD-BASED HIGH SCHOOL GEOLOGY COURSE: IGNEOUS AND METAMORPHIC TERRAINS - AN ISRAELI EXPERIENCE

INTRODUCTION: GEOLOGY IN ISRAELI HIGH SCHOOLS

Three years ago the Ministry of Education in Israel decided, that geology should be taught at high school as an independent, non-obligatory subject. This decision was the result of favourable voices raised in both the geological and teaching communities. A nominated committee has recently handed to the Ministry its detailed recommendations on geology teaching in different courses of 1 to 5 credit points (out of minimum 22 credits needed to finish high school). The recommended courses include:

1. **General Geology** (2 credit points; teaching package exists);

2. **Chemistry of Minerals and Rocks Common in Israel** (1 credit point; teaching package exists: see Pezaro et al 1978);

3. **Igneous and Metamorphic Rocks: Eilat Timna** (1 credit point; the topic of the present manuscript), and

4. **Geotop** (research projects, 1 credit point, in preparation).

Geology is a recent intruder into Israeli High Schools. The reluctancy to promote it so far is explainable by:

a. an indifference towards school geology of the founders of professional geology, who were isolated in their academic ivory towers. This resulted in:

b. a lack of approval of high-school teaching as a future for a geologist;

c. a lack of written material that could be used in a proper manner in schools and

d. an apprehension of most science teachers when faced with conducting field excursions. This stemmed from the fact that the conducting of field excursions poses many logistic problems.

Since a large proportion of the Israeli scenery is arid and the vegetation and soil covers are thin, the very varied geology is well exposed. Becoming familiar with common rocks and basic geological features in such landscapes creates understanding and positive attitudes in students towards the natural environment. As a learning discipline geology provides an excellent example of the scientific methodology and the linkage which is possible between observation, deduction and the formulation of hypotheses each of which may be tested in the light of new observations. The General Geology course, cited above, deals with these aspects.

The other courses are aimed at strengthening specific aspects of interdisciplinary nature, e.g. geochemistry, geophysics and biology (which has yet to be prepared) or topics of basic importance, such as the study of igneous and metamorphic rocks.

All courses in geology developed for secondary schools are based on teaching packages written in Hebrew, and they lean heavily on the use of accessible outcrops, the teacher's guide, sign-posted geological trails, laboratory kits, films and posters.

This manuscript is an attempt to describe the development and implementation of the teaching package on Igneous and Metamorphic rocks.

THE STRUCTURE AND CONTENT OF THE COURSE IN IGNEOUS AND METAMORPHIC ROCKS

The course is divided into three units:

a. **An introductory unit**, taught in the class and laboratory (about 30 teaching periods);

b. **A field workshop:** a four-day camp in the Eilat-Timna region (see Fig. 1);

c. **A summary unit**, again taught in the classroom and laboratory (about 20 teaching hours).

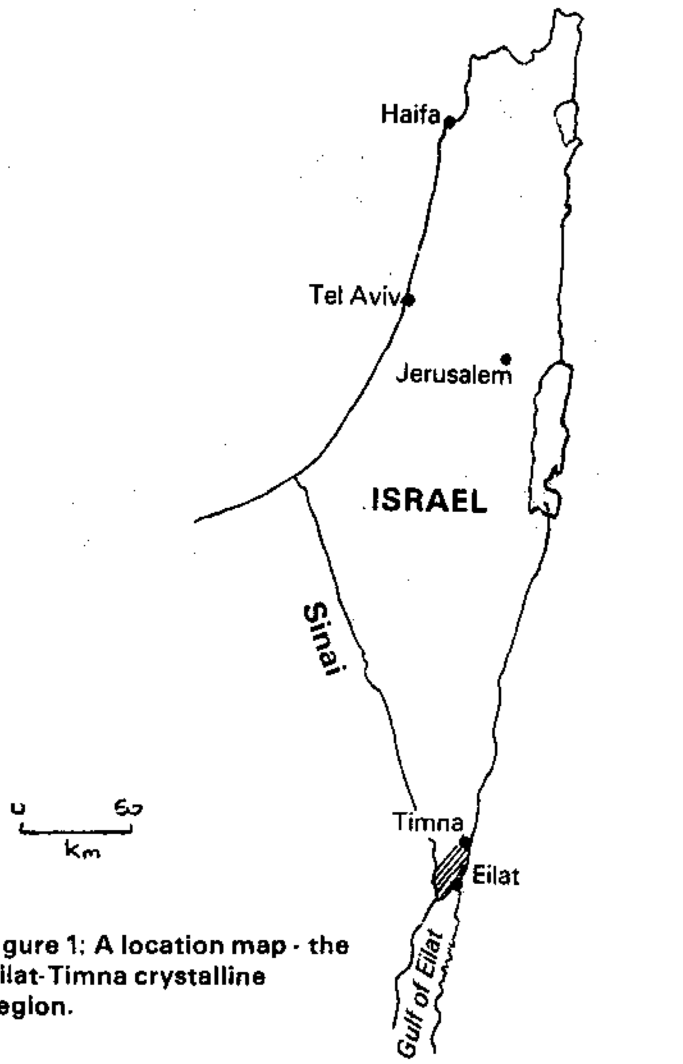


Figure 1: A location map - the Eilat-Timna crystalline region.

The main concepts and learning activities used in these units are described in Table 1.

Units	Concepts
1. INTRODUCTORY	a. **Introduction to igneous rocks:** crystalline structure, magma, rate of cooling. Plutonic environment: plutonic rocks, granite, gabbro. **Volcanic environment:** lava volcanoes, rhyolite, basalt, pyroclastic rocks, ignimbrite. **Silicate minerals:** quartz, feldspars, mica.
	b. **Introduction to metamorphic rocks**: schist, gneiss. **Mechanical changes:** folding and reorganization of minerals, lineation, foliation. **Mechanical changes:** folding and reorganization of minerals, lineation, foliation. **Chemical changes:** metamorphic minerals, metamorphism, regional metamorphism, zoning, metamorphic environment.
	c. **Preparation for the field workshop:** geographical and geological acquaintance of the Eilat Timna region by maps, air photographs and slides.
2. FIELD WORKSHOP	a. **Field identification of:** granite, syenite, diorite, rhyolite, ignimbrite, porphyry dyke, xenolith, quartz, feldspar, biotite, muscovite, schist, gneiss, biotite schist, garnet schist, staurolite schist, migmatite.
	b. **Mapping of rock units.**
	c. **Geological structures:** folds, normal faults, graben, horsts.
	d. **Field relations and reconstruction of geological history.**
3. SUMMARY	a. **Summary of the field workshop:** the geological map, type of metamorphism, relative ages and radioactive ages.
	b **Eilat region and the Arabo-Nubian massif.**
	c. **The variety of igneous rocks:** the silicate groups, classifications, Bowen's reaction series, fractional crystallization, composition of magmas.
	d. **The interior of the crust.**
	e. **The igneous and metamorphic rocks and plate tectonics.**
	f. **The rock cycle.**

Table 1. The content of the course on igneous and metamorphic rocks.

THE CURRICULUM PACKAGE

The term "curriculum package" is used to describe the wide variety of instructional materials that are available for use in the course. The geology currciulum provides the teacher with a variety of possible instructional techniques which help in breaking down the monotony of the teaching/learning process (Kolesnick 1978). The curriculum package developed for this course gives the teacher and students the option of selecting from a variety of learning activities that could be used in individual learning, small-group activities (for 2-3 students), teacher's lectures, classroom activities and audio-visual presentations.

The instructional techniques used in this course are presented in Table 2.

Course units	Learning Materials
1. INTRODUCTORY	1. **A students' text and work booklet.**
	2. **Rocks and minerals kit:** including 12 hand specimens of the igneous/metamorphic rocks and minerals from the Eilat-Timna region.
	3. **Thin section laboratory:** including mini-polarizing microscopes; thin sections; explained colour microphotographs of the thin sections; **worksheets.**
	4. **Posters:** "Common rocks of Israel", "Common minerals", "Folding and minerals in metamorphic rocks".
	5. **Maps and air photographs:** of the field-workshop region.
	6. **Colour slides** of the field-workshop region.
	7. **Films:** "Rocks and landscapes", "the world of rocks of Eilat".
	8. **Teacher's Guide.**
2. FIELD WORKSHOP	9. **Sign-posted geological trails.**
	10. **Field worksheets,** based on sign-posted stations on the trails.
	11. **Summary booklet** which contains suggested solutions to the problems posed to the student on the field worksheet.
	12 **Mini posters** for the teacher, to show drawings, geological sections and illustrations.
	13. **Teacher's guide.**
3. SUMMARY	14 **A Booklet,** which includes an enrichment text.
	15 **Thin-section laboratory** (see above).
	16. **Film:** "The Rift and continental drift".
	17. **Poster:** "Main stages in the geological development of the Eilat region".
	18. **Teacher's guide.**

Table 2. Instructional techniques used in the course on igneous and metamorphic rocks.

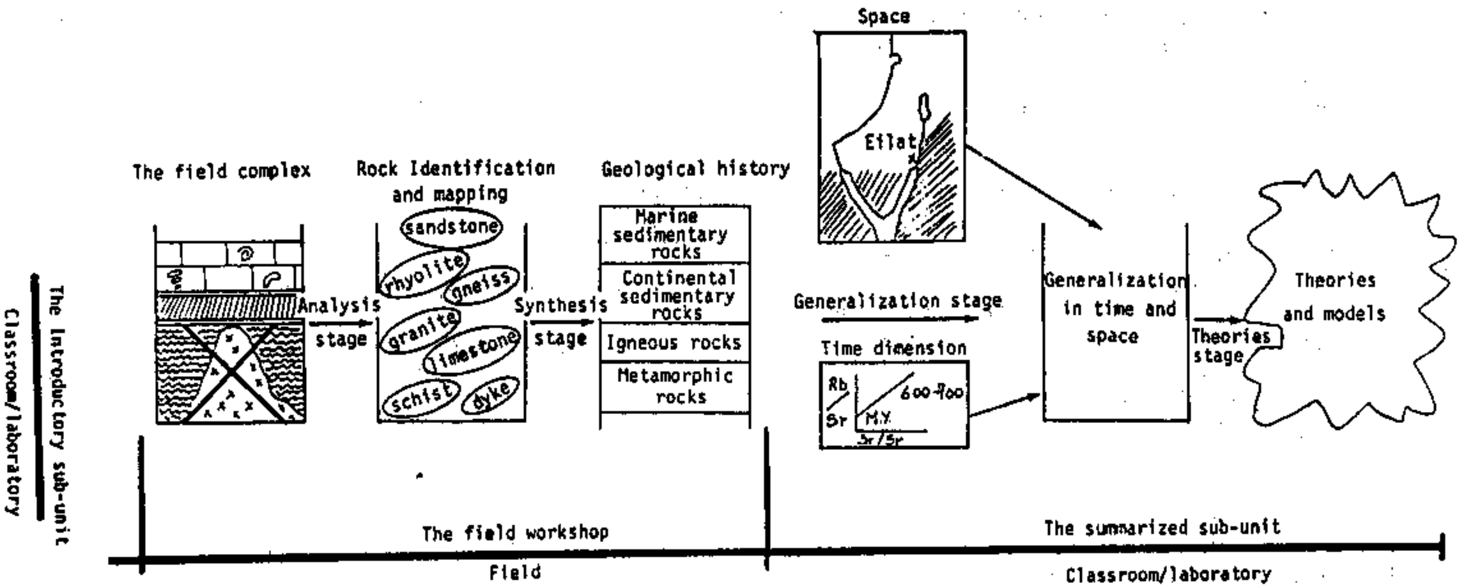


Figure 2. The didactive structure of the course.

THE TEACHING APPROACH OF THE COURSE

The course consists of three parts

1. **Class/ laboratory** (the introductory unit);
2. **Outdoor experience** (the field workshop, and
3. **Class/ laboratory** (the summary unit).

The theoretical background to this model is based both on Piaget's (1970) and Ausubel's (1968) theories of learning.

On the basis of Piaget's theory, the students are provided with several practical experiences (i.e. hands-on experiences) which make the material more "concrete" and substantial. It is suggested that by providing the students with such experiences they will be helped to cope with more formal learning activities which come later. On the basis of Ausubel's (1968) theory of "meaningful-learning", the course is organized in such a way that every concept is used as an 'advanced organizer' and an anchor for the learning of the next concept which is usually more complex and more complicated.

The introductory unit

The main purpose of this unit is to prepare the students for the field workshop. This was done in order to reduce the impact of what Falk et al. (1978) and Marin et al. (1981) call the "novelty" effect of the field trip. They suggest that when students arrive at a new environment their learning abilities decrease, since their attention is first directed to the exploration of new phenomena in a general sense.

Orion (1985) suggests that the novelty could be desrcibed as consisting of three components: the learning concepts, the physical location and students' outdoor experiences. The introductory section deals with the first component in the following manner.

The students learn to identify about 15 rocks and they are also introduced to some new concepts, e.g. magma, plutonic rocks, volcanic rocks, metamorphic rocks and foliation.

The introductory unit is aimed at initiating students' acquaintance with the geography of the field area. This takes place in the classroom using maps, air-photographs, films and slides.

The learning always starts with the students handling a variety of learning materials: hand specimens of rocks and minerals, thin sections under the microscope, posters, films, slides and air-photographs.

The field workshop

After the introductory phase, the students start a 4-day field workshop. The learning in the field workshops can be described in four stages:

Stage 1 Analysis. On arriving in the field, students are introduced to a very complicated geological setting. At the beginning of this phase students are helped to analyse the geological set-up by dividing it into units using their skills in the identifying of rocks and their geological maps. Then, dependent on the field relations of the rock types, they identify their relative ages.

Stage 2 Synthesis. In this stage students are reconstructing the geological history by adding all the information obtained thus far. Following this, students return to the classroom to take the last unit. This part consists of two additional stages (Fig. 2):

Stage 3. Generalization. The students are provided with the absolute ages of the rocks which they had previously observed in the field and also with some geological sections of the Arabo-Nubien massif. Using this data, students are assisted to generalize their findings in space and time.

Stage 4. Theorizing. The students are offered information from field and laboratory researches conducted by generations of previous geologists. The students consider various models and theories on the origin of the igneous and metamorphic rocks.

THE LEARNING CYCLE

The learning cycle set down below in stages a. to d. was developed in order to teach the course. Similar learning cycles were suggested and used by Renner and Lawson (1973) and by Karplus and Lawson (1974).

Stage a. **Observation and investigation** of materials.
Stage b. **Obtaining information** from the course material and from the teacher specially in field workshop.
Stage c. **Drawing conclusions.**
Stage d. **Raising questions based on the conclusions;** 'paving' the road for the next learning cycle.

The use of the learning cycle in this course is demonstrated by the first two activities in the introductory booklet. The objectives of these activities are: the identification of granite and rhyolite and the learning of basic geological concepts relating to rates of cooling, plutonic and volcanic rocks.

Stages	Contexts
Observation 1	Students are asked to take the rock specimens marked no. 1 and no. 2 from the rocks kit. (These are granite and rhyolite, but the students don't know this until the end of the activity). The students are asked to observe the rocks very carefully and to compare them.
Conclusion 1	They do not find a significant similarity between them
Observation 2	Students are asked to look at thin sections of the rocks.
Conclusion 2	A worksheet helps them to observe that the samples have a crystalline structure but that there is a difference in the crystal size.
Obtaining of information	Students receive "outside" information: a table with the chemical compositions of seven different rocks, including data relating to samples 1 and 2.
Conclusion 3	At this stage, students are able to conclude that the samples 1 and 2 have similar chemical compositions.
Summary conclusion of cycle 1	At the end of this cycle, one can conclude that the two kinds of rocks differ only in the size of the crystals of which they are composed.
Questions opening a new cycle	Students are left with a question. This can serve as a starter for a new cycle: what caused the difference?

Cycle No. 1. Comparison between granite and rhyolite.

Observation 1	The next learning cycle starts with an experiment. Students are directed to melt a powder of an organic compound, Salol ($C_{13}H_{10}O_3$), that has a low melting point (45°C). Students pour the melt on two microscope slides: a warm one and a cold one, the latter resting on ice.
Conclusion 1	The liquid on the cold slide crystallises rapidly and in small crystals. In contrast, the liquid on the warm slide crystallises much more slowly, but in large crystals.
Obtaining of information	This is used by the teacher as a model to illustrate the following concepts; cooling rate, rock melting (magma), plutonic rock and volcanic rock.
Conclusion 2	At the end of this cycle, the student is able to conclude that samples 1 and 2 were probably cooled and crystallised from the same magma, but one, sample 1, cooled slowly deep in the earth's crust, while sample 2 was cooled rapidly on the surface.
Obtaining of information	Students are told that sample 1 is called granite and the other is called rhyolite.
Raising questions ...new cycles	This information and these conclusions, which have been derived, open up more questions and introduce other learning cycles.

Cycle No. 2. Crystal size and rate of cooling experiment.

PRINCIPLES OF PLANNING OF THE FIELD WORKSHOP

Principles of planning of trails

a. Stations should all be located within walking distance from each other.
b. The trail should be scientifically attractive and enjoyable to follow.
c. Trails should be planned so that it will be convenient in terms of transportation of participants, and for the setting down and collecting of students.
d. Each trail will relate to a major theme in the conceptual framework.

Principles of planning of stations

a. The learning in the field should be conducted at well-defined stations. Each station must be marked in the field, so that both teachers and students will locate them easily.
b. The exposure has to be clear enough as "to speak for itself".
c. There has to be enough room around the station for the uninterrupted activity of at least 20 students.
d. The microclimate of the station should not inhibit work: lack of shade, over exposure to sun, wind or blowing sand are not conducive to mental or physical endurance.

The learning method in field workshop

a. Students should work in small groups of 1-3 students, their learning being directed by worksheets. After they have discussed their observations of the geology of the station among themselves, there should be a class discussion which should be led and summarized by the teacher.

b. Planning the activities has to take into account the problems which relate to the "novelty of the new setting". A way to avoid difficulties is to focus at the first stage mainly on sensoric activities that lead to a familiarity with the rocks and the new environment; only later should the students deal with more analytic activities.

DESCRIPTION OF THE FIELD WORKSHOP TRAILS

Four trails were prepared:
Trail 1. The main topics which are studied are the plutonic rocks and the geological sequence. Since the trail is the students' initial experience with the environment, the activities are based on the material that was learned in the introductory unit i.e. rock indentification. This trail consists of 10 stations and it takes 5/6 hours to explore.
Trail 2. This trail is divided into two parts. In the first half of the day, the students climb the highest mountain in the area and learn about the geography and the general geological structure of the area. In the second part, the main topic is the volcanic rocks. The two parts are connected by a scenic walk, during which no formal learning takes place and students can enjoy the scenery. The number of stations is 10 and it takes 7/8 hours to complete the route.
Trail 3. This trail deals with metamorphic rocks, field relationships and relative ages of crystalline rocks. There are 8 stations in this trail and the duration of the trip is 4/5 hours.
Trail 4. This trail is limited to a small area where there are about 10 exposures (as small as 2m x 2m) displaying clear field relations of different types of rocks (granite, schist, gneiss and dyke rock). Teams of students are asked to identify the rocks, to investigate their field relationships and to determine their relative ages. Each team works two hours in the station and then the teams are asked to share experiences and their results with other groups. This is followed by a discussion which is summarised by the teacher.

THE IMPLEMENTATION OF THE UNIT IN SCHOOLS

The unit was tried in three schools during the academic year 1984. About 50 students were involved in this trial version. In order to assess the educational effectiveness of the various instructional methods used in this unit, both formal evaluation methods (i.e. students' and teachers' questionnaires) and naturalistic methods (i.e. the use of a case study which combined observations during and after the field trips) were used.

The results that were obtained from the quantitative data (based on the questionnaires) and the informative data collected in the case study, revealed the following:

1. The students gained scientific knowledge.
2. The students enjoyed the learning.
3. Attitudes to geology and the natural environment were significantly improved after the learning.
4. The use of worksheets by teams in the field, followed by group discussion, were found to be effective teaching strategies.
5. Learning efficiency in the field was influenced by many factors: the skill of the instructor, quality of the worksheets, the previous knowledge of the students, their experience in the field and their geographical orientation. These variables need to be assessed by further research.

It is suggested that in order to make such field trips usable for teachers, the field stations have to be marked on the ground, each station has to be explained at length and discussed in the teachers' guide, and preparatory reconnaissance trips have to be conducted by the teachers concerned.

It is believed that this approach to teaching is an effective one and can be used to teach other topics in geology.

The information obtained in this study was found to be useful for the rewriting of a new version of this unit and for further future development and implementation of geology curricula.

References

AUSUBEL, D. 1968 Education Psychology. New York: Holt, Rinehart & Winston.

FALK, J. H., MARTIN, W. W. & BALLING, J. D. 1978. The novel field-trip phenomenon: Adjustment to novel settings interferes with tasks learning. Journal of Research in Science Teaching, 15, pp. 127-134.

KARPLUS, R. & LAWSON, A., Eds. 1974. SCIS Teacher's Handbook. Berkeley, California: Lawrence Hall of Science.

KOLESNICK, W. B. 1978. Motivation: Understanding and influencing human behaviour. Boston, Allyn & Bacon.

MARTIN, W. W., FALK, J. H. & BALLING, J. D. 1981. Environmental effect on learning the outdoor field trip. Science Education, 65, pp. 301-311.

ORION, N. 1984. Development and Evaluation of Geology Curriculum Igneous and Metamorphic rock - Eilat Timna: Unpublished M.Sc. Dissertation. The Weizmann Institute of Science. (in Hebrew).

PEZARO, P., MAZOR, E., & SAMUEL, D. 1978. The chemistry of rocks and minerals. Journal of Chemical Education 55(6), pp. 383-385.

PIAGET, J. 1970. Structuralism. New York: Basic Books.

RENNER, J. & LAWSON, A. 1973. Promoting intellectual development through science teaching. The Physics Teacher, 11, pp. 273-276.

Nir Orion* and Avi Hofstein, Department of Science Teaching, The Weizmann Institute of Science, Rehovot 76100, Israel. and Emmanuel Mazor***, Geo-Isotope Group, The Weizmann Institute of Science, Rehovot 76100, Israel.**

*This study was conducted as part of the author's MSc dissertation at the Feinberg Graduate School of the Weizmann Institute of Science, Orion (1984). More details about the project could be obtained from the authors.

**also coordinating inspector for high school chemistry, Ministry of Education and Culture, Jerusalem.

***The Frank Considine Professorial Chair in Hydrological Research.