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Report of the

Consultants' Meeting

on

Applications of Accelerator Based Analysis

IAEA Headquarters

Vienna, Austria

20-22 July, 1998

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1. Introduction

This meeting is a continuation of several previous CMs which dealt with the accelerator based analysis techniques and their applications. At the CM on *Present Status of Low Energy Accelerators*, Debrecen, Hungary, June 1992, technical aspects related to low energy accelerators were discussed. At the CM on *Use of Low Energy Accelerators for Characterization of Materials, IAEA Headquaters, December 1993*, several ion beam analysis techniques and interesting fields for their applications were identified. Following these two meetings, applications of Ion Beam Analysis (IBA) techniques to aerosols and semiconductors were discussed during the AGM on *Accelerator-based Nuclear Analytical Techniques for Characterization and Source Identification of Aerosol Particles*, Ljubljana, Slovenia, 1995, and CM on *Ion Beam Techniques applied to Semiconductors and related Advanced Materials*, Vienna, April, 1996. At the CM on *Accelerator Mass Spectrometry (AMS)*, Zagreb, April 1995, various aspects of AMS were discussed.

At the present meeting, applications of accelerator based analytical methods, often referred as ion beam analysis (IBA) methods, to the following areas have been discussed:

- Materials (including thin films),
- Earth Sciences (including Environmental Studies),
- Biology and Medicine,
- Art and Archaeology (Cultural Heritage),
- Other applications (including forensic applications).

This report gives brief overview of IBA applications in these areas, with short background about accelerators needed and corresponding analytical techniques.

2. Types of Accelerators

There are basically three types of accelerators in the energy region of interest for analytical applications (typically one to ten MeV). These are electrostatic accelerators, linear accelerators (particularly radio-frequency quadrupole accelerators) and cyclotrons. The most widely used of these are the electrostatic accelerators.

3. Accelerator based analytical techniques

It may be useful to briefly recount the principles of the IBA techniques. For an analysis measurement a beam of high-energy (MeV) ions is aimed at the sample. These projectiles penetrate rather deeply (in the order of micrometer), losing energy continuously at a well-known rate. Along their trajectories there is the chance for collisions with nuclei and inner-shell electrons. The products of these interactions are emitted from the surface and from inside the sample, with probabilities determined by the respective interaction cross-sections, and are measured as signals carrying information on the chemical elements and their depth distributions. There are four major IBA techniques:

- In RBS (Rutherford Backscattering Spectrometry) one records projectiles elastically backscattered from nuclei of sample atoms. The measured energy depends on the mass of the target nucleus (and thus on the element or isotope) and also on the depth of the scattering event beneath the surface.
- ERDA (Elastic Recoil Detection Analysis, sometimes abbreviated ERD or ERA) is also based on elastic scattering. One records the target nuclei recoiled by the scattering of projectiles. The measured energy depends on the mass of the recoil and on the depth of the scattering event.
- NRA (Nuclear Reaction Analysis) relies on the measurement of the products (p, d, alpha, gamma, etc.) of nuclear reactions between projectile and target nuclei. The recorded energy of the products gives information on the specific target nucleus and, except in the case of gamma rays, on the depth of the reaction event.
- With PIXE (Proton/Particle-Induced X-ray Emission) one measures X-rays arising from the filling of inner-shell vacancies produced by the projectiles. The X-ray energies are characteristic for the respective elements.

The full range of different techniques with ion beams includes many other methods based on these principles. For example there are Particle induced Gamma-ray Emission (PIGE), Charged Particle Activation Analysis (CPAA), Scanning transmission ion microscopy (STIM) and Ionoluminescence.

One of the most important features of this type of approach is the ability to bring many of these methods to bear simultaneously in the multitechnique approach. The power of these methods is greatly increased by the use of scanning microbeams in the nuclear microscope.

In addition to the traditional areas of Ion Beam Analysis, the analytical applications of accelerators also include Accelerator Mass Spectrometry (AMS) and methods using accelerators as neutron sources.

Modern accelerators increasingly allow the use of accelerator produced neutrons. In addition to the traditional methods of fast neutron activation, low energy high current accelerators provide intense neutron fluxes allowing for the use of thermal neutron activation on samples of a few grams and for the application of resonance neutrons for elemental imaging in the detection of explosives and other applications.

4. Applications

4.1. Materials

The decisive features of most modern technological and industrial products with improved properties or novel functions are largely determined by the composition and structure of the material at and near the surface which is in general quite different from the bulk. This material may be the edge zone of the bulk altered by some process or, more frequently, a thin film deposited onto the bulk material.

Clearly, analytical methods for characterizing surfaces and thin films play an important role in the development of production processes and in related research. Because of the depth information that they provide, the three IBA techniques, RBS, ERDA and NRA are a valuable complement to more conventional surface analytical techniques: AES (Auger Electron Spectroscopy), ESCA (Electron Spectroscopy for Chemical Analysis) and SIMS (Secondary Ion Mass Spectrometry), and they have some unique features which make them indispensable for certain problems.

All elements can be detected with the IBA techniques. NRA and ERDA are more suitable for light elements and in particular for hydrogen, RBS is complementary. Of the non-accelerator-based techniques only SIMS can analyze hydrogen. Isotopes can be distinguished with NRA, in some cases with ERDA, and also with SIMS. This capability is useful in studies of growth- and transport processes.

A very important property of the IBA techniques, not shared by the three other techniques, is that they yield quantitative concentration values. This derives from the fact that the cross sections of the high-energy interactions are not influenced by chemical bonding. The detection limit attainable with the IBA techniques is in the range of several hundred to a few ppm, depending on the technique and the matrix composition. Whereas AES and ESCA are less sensitive, SIMS is outstanding in this respect.

Concerning depth resolution, the three low-energy techniques are superior to RBS, ERDA and NRA by an order of magnitude. However, for obtaining a depth profile, the low-energy techniques require sputter ablation of the sample, whereas the information depth of the IBA techniques is in the order of one micrometer and thus much larger than the depth resolution. This represents a unique, attractive property : depth profiles are obtained without the destruction of the sample, the depth resolution being about one hundredth of the information depth. Furthermore, dynamic processes, such as film formation or stoichiometric change inside a sample, can be followed (quasi)continuously in real time if they occur on a time scale comparable with that of the IBA measurement.

Finally, when studying crystalline materials, the IBA techniques can be used in combination with channeling. Then, quantitative information on the state of lattice order can be derived and the lattice sites of foreign atoms can be determined.

The following list of examples of materials, film configurations, processes and phenomena is intended to demonstrate the richness of themes amenable to study by the accelerator based analytical techniques:

> *Metal surface-alloys, metal-metal multilayers, metal hydrides, conducting and insulating layers in micro-electronics, superlattices, SiO_2/Si interface, porous silicon, solar cell materials, magnetic films, HTc-superconductors, catalyst films, novel ceramics, carbon-based materials, biocompatible surfaces of metals and ceramics, polymer films, protective coatings against wear and corrosion, optical coatings on glass, film formation by deposition (PVD, CVD, sputtering, spin coating, MBE), ion implantation, ion mixing, diffusion, annealing of defects, phase transitions, interface segregation, ion-beam-induced species loss,*

plasma-wall interactions in fusion devices, leaching and hydration of glasses, oxydation, nitridation, gas uptake and release, sputter ablation, surface segregation, adsorption, vibration of surface atoms, ordering of macromolecules in polymer films.

This listing is not exhaustive. On the contrary, new themes appear continuously along with new developments in materials science and technology. It can be foreseen that the capabilities of the IBA techniques will make them indispensable in supporting these developments.

4.2. Earth Sciences

There is a large multitude of research projects in the different areas of the Earth Sciences (including the Environmental Sciences) and given the correct staff, a modern and well equipped accelerator and an adequate research budget there are many fascinating and important inter-disciplinary projects in these fields. This applies particularly to IBA laboratories equipped with Nuclear Microscopes and to Accelerator Mass Spectrometry Laboratories.

If the laboratory must also make an input to the economy in the short term, and this is a demand that is being made more and more - it is probably essential in developing countries -, then it is necessary to examine the techniques critically. It must be seen in what respect they have a competitive edge in areas where there is an analytical demand. This can be expressed by saying that they must be competitive when used for routine analysis in some application.

In the Earth Sciences (in its broadest interpretation), there are three fields in which accelerators clearly have particularly important role to play. These are the applications of PIXE (and other IBA techniques) to environmental problems, research in mineralogy, and the application of AMS to the measurement of ^{14}C, for dating and, again, environmental applications.

4.2.1. Aerosol Analysis

In the case of pollution studies and the understanding of the global climate it can almost be said that ion beam analytical methods have become the methods of choice. In the analysis of aerosols that are correlated with the time and date using the streaker method, it is necessary to measure the composition of very small sample masses and it is here that PIXE and the other ion beam analytical techniques are particularly powerful.

This is becoming of particular importance in the development of Global Climate Models (GCM) to understand the impact of human activities on global warming and the climate in general. Once again here the ability to analyze very small sample masses is of the greatest importance and makes accelerator based methods, the method of choice in a number of cases.

In South Africa the PIXE method is used quite regularly in source apportionment studies. In this type of study the streaker data is characterized in terms of source using its elemental composition as a signature. It is then correlated with meteorological data to establish whether it is marine, dust or anthropological in nature. This method has also been used for studies of biomass burning and its effects on aerosols over Southern Africa. This work is of great interest in the context of global climate modeling.

PIXE is the method of choice for the analysis of aerosols as a function of the particle size. This is because PIXE needs only small masses to be quantitative. It has a very low absolute limit of detection in the nanogram, or fraction of a nanogram region.

4.2.2. Analysis of minerals (Mineralogy)

Methods of ion beam analysis and particularly those involving the nuclear microscope have found many research applications that are of great interest. It is not yet clear how many of these techniques have established themselves in applications of routine importance, but many of them have great potential.

The nuclear microscope has been extensively applied to problems in the Earth Sciences in Australia, Holland and South Africa. For example these methods have been used in an examination of economic mineralisation in the case of pyrite. PIXE images were collected to provide details of the trace element associations during the growth of pyrite. The pyrite is characterized by dramatic oscillatory zoning. The results illustrate the power of the nuclear microprobe. The levels of the elements, in the ppm range, would be too low to be detected by a conventional scanning electron microprobe.

Another interesting application has been the use of *micro-channeling* to investigate the manner of occurrence of gold in pyrite, whether as metal particles or in solid solution. Using this method it was possible to image Au at trace levels. The data showed at least a 50% substitutional Au component.

In an interesting new development, Yang et al. have applied the method of *ionoluminescence* to the investigation of zircons to determine areas of lattice defects that might indicate areas of high diffusion leading to potential errors in dating.

The PIXE method with the nuclear microscope has also been used for the investigation of ore forming processes in porphyry ores (Cu, Mo and Au). The unique penetrating property of the high energy ion beam has been used to analyze unopened fluid inclusions. This is a unique application of the nuclear microscope technique because of its ability to penetrate tens of microns into the specimen.

Crystallization phenomena occur in the heart of volcanoes, in the areas of the magmatic reservoir that are less hot. As crystals grow, they trap droplets of lava that are quenched into glass when the lava suddenly cools. The analysis of these droplets yields important data relating to the temperature and pressure conditions during the formation of the host mineral and traces the evolution of the magma during a complex process.

These applications show some of the power of ion beam methods, and particularly of the nuclear microscope, as research tools in mineralogy.

4.2.3. Applications of AMS in the Earth Sciences

AMS is a recognized tool for dating in archaeology but more recently its application has been considerably extended in the Earth sciences particularly through the use of the cosmogenic nuclides ^{10}Be, ^{26}Al and ^{129}I. It promises to become a powerful method in studies of oceanography, paleo-climatology and geo-hydrology (ground water resources). Although it is more demanding than many other accelerator-based methods, it shows great promise for the future.

4.3. Biology and Medicine

Applications of accelerator-based analysis in medicine and biology were not numerous until the advent of PIXE in the beginning of the 1970s. Before 1970 neutron activation analysis, both radiochemical and instrumental, was the dominant nuclear technique.

Since the 1970s, an increasing interest has been demonstrated both from medicine and biology. Rather than a comprehensive review a few applications in selected sub-disciplines will be exemplified. The subdivision is somewhat arbitrary: cell biology, organ biology, pathophysiology, botany, pharmacology and toxicology. To contribute to cell biology, there is a need for a nuclear microscope with a spatial resolution of about 5-10 μm or better. There is a wealth of problems, however, that can be addressed with broader beams and the difference between broad-beam, millibeam and microbeam analysis will eventually turn out to be academic.

4.3.1. Cell biology

Multielement studies of fibroblast cells have been shown to be a possible basis of rapid diagnosis of Menkes' disease. Discriminant analysis of data formed from ratios of copper to each of the minor elements in individual cells implicates that normal cells can be discriminated from sick cells. Blood cells from ascidians containing extraordinarily high concentrations of vanadium have been investigated to shed light upon the function of this trace element. Using nuclear microscopy, it has been shown that even mitotic cells (dividing cells) may have the property of apoptosis (programmed cell death).

4.3.2. Organ biology

Investigations have been made at several levels of spatial resolution. With quite broad beams, contributions have been made to the understanding of cataracts. Ion distributions in the human amnion have been extensively studied to improve on the understanding of ion transport. Applications to the field of dermatology have been especially successful, leading to a better understanding of pathological skin lesions such as psoriasis and atopic skin. Approaches have even been made to Parkinson's disease showing that there is an increased concentration of iron in the damaged areas of the substantia nigra (containing the dopaminergic cells). Selenium protection against the toxicity from cadmium and mercury has been demonstrated in both kidneys and livers.

4.3.3. Pathophysiology

An extensive amount of research has been directed to the understanding of trace-element involvement in inflammatory connective tissue diseases like rheumatoid arthritis and certain types of leuchaemias. This has been based on the nuclear microscopy of individual isolated blood cells. Hair has been used in various applications including assessment of metal exposure following a water pollution accident where lead was mobilised into drinking water. Hair has also been used for the study of Wilson's disease. Discriminant analysis of a large data set, including trace elements, from patients suffering from porphyria showed that granulocyte manganese was one of the important discriminating factors between patients and controls. Neurofibrillary tangles and neuritic plaques in Alzheimer's disease have been screened for aluminium showing that the detectable presence of this element most probably is due to contamination. This finding, however, contradicts a current hypothesis.

4.3.4. Botany

The advancement of accelerator-based analysis into this area remains slow. Some studies have been made on tree rings from various species to improve on the knowledge of transport processes and dating. Single seeds have been probed for their protein depth distributions to assist in plant breeding to improve on the nutritional quality.

4.3.5. Pharmacology

Most work has been done with nuclear microscopy improving the data on uptake and distribution of various drugs, such as anti-AIDS drugs, in cellular model systems, although trace elements in anti-convulsant drugs have been studied with broad beam PIXE. The increasing interest in trace-element roles in traditional drugs in developing countries warrants further investigation.

4.3.6. Toxicology

Early applications include the study of lead distribution in femoral cortical bone from workers having been occupationally exposed. Nuclear microscopy was additionally used to unveil lead distributions in the construction units of compact bone (osteons). Contributions to understand cellular perturbations of trace-element balances in blood cells have been made using nuclear microscopy. Particularly, the consequences of exposure to mercury has been studied. Selenium protection against mercury toxicity is being studied at the cellular level.

4.3.7. Environmental-chemical archives

Using mineralised tissues from different species, age-related information can be extracted. For example mussels lay down a layer of carbonate each year in their shells. Trace and minor elements passing through the mussel are incorporated into the incremental layer thus providing information about the chemical environment. For example, changes upstream of the mussel site can be traced and dated. Otoliths from fish have been used in a similar manner providing information about fish mobility.

4.3.8. Applications of AMS in Biology and Medicine

Having been mostly used for dating purposes, AMS is an emerging technique in biology and medicine. AMS has several appealing features; firstly, the requirement of very small sample volumes, secondly the use of radioactive traces can be minimised and thirdly, the use of radioactive nuclides may be exchanged for stable nuclides. This opens exciting possibilities.

4.4. Art and Archaeology

IBA techniques, and particularly PIXE because of its high sensitivity, constitute a powerful tool for the knowledge, the conservation and the restoration of cultural heritage. In addition to their excellent analytical performances, they have a feature of prime importance in the context of works of art and archaeology, namely their non-destructive character. A marked improvement has been to design experimental set-ups allowing the in-situ analysis of works without sampling. This is achieved in external beam lines where the ion beam produced under vacuum is extracted through a thin exit window and strikes the sample in air. This kind of set-up has gained great popularity because of the extreme ease of operating IBA techniques in air. Additional advantages are: (i) the possibility of handling objects of all sizes and shapes; (ii) the analysis of fragile objects which could be damaged by vacuum; (iii) the reduced heating of the targets; (iv) the absence of charging of insulating materials.

About 30 groups in the world are active in this field. About half of them belong to Western European institutions associated in the framework of a COST action (Scientific and technical cooperation) of the European Commission. A comprehensive survey of recent works will be given in the TECDOC (see recommendation 1). These works can be classified according to various issues of art history, conservation and archaeology. In *art history*, the main objective is to provide an insight on the technique of the artist via the identification of the raw materials he has used, the way they are mixed and the treatments subsequently applied. This can yield strong arguments for the authentication of the work, its attribution to a particular artist or a studio. Concerning *conservation-restoration*, the knowledge of the chemical composition and particularly the depth distribution of elements is essential to check the state of conservation of the object and to possibly infer the ageing mechanism by comparison with experimentally altered materials of similar composition. In addition this can give guidelines for the choice of the best restoration techniques. In *archaeology*, the main purpose of artifact characterization is to get an insight on the technical development over the distant past as well as to identify the sources of materials and trade routes. It also offers the possibility of indirect dating of artefacts through compositional similarities with well dated materials. In practice these issues are addressed by performing measurements of increasing sophistication and duration in order to identify:

(i) the nature of the constituent materials of the artistic or archaeological artifact via the analysis of major elements. This is the basic objective of the scientific characterization of museum objects and provides important clues for the knowledge of the fabrication procedure and for the authentication of the work of art. This task is quite easily performed by PIXE in external beam mode. This approach is illustrated by several investigations performed on manuscripts, miniatures and drawings and intended to identify the nature of inks, metal points and pigments;

(ii) the provenance of materials by means of their trace element fingerprint. This issue is probably the most frequently addressed in archaeological works, because it is the key toward the knowledge of ancient trade routes and links between populations. The current methodology combines PIXE trace element analysis on both artifacts (most often made of stones like obsidian or flint) and samples of well defined geological sources and multivariate statistical methods;

(iii) the fabrication technology for materials thermally or chemically transformed, or for composite materials, e.g. layered ones like glazed ceramics, soldered metallic objects, etc.. The knowledge of the spatial distribution of elements is essential. This can be provided by using RBS/NRA for depth profiling and microbeam for elemental micromapping;

(iv) the alteration processes due to burial or aging. Depth profiling of light elements including hydrogen due to aqueous corrosion, is of prime importance. Much effort is currently done to develop methods based on (d,p) nuclear reactions on elements such as C, N, O, S, which can be implemented on external beam lines;

(v) the indirect dating of artifacts. This can be inferred by comparing the chemical composition of a characteristic component (for instance the ink on a manuscript or a pigment in a painting) with that of their counterpart in well dated works. Some examples of dating based on an alteration criterion should also be mentioned: depth penetration of hydrogen in obsidian tools or of fluorine in flint tools.

Applications of AMS in archaeometry are almost restricted to the isotopic analysis of carbon for dating by the ^{14}C method. The high sensitivity of the technique has permitted to markedly reduce the amount of material needed for analysis and thus explains its growing popularity among archaeologists. About 10 laboratories around the world are doing this kind of measurements and this number will likely increase in the near future.

4.5. Other applications

With the advent of accelerators with energies in the range of a few MeV and high beam currents (of the order of 100 μA to 1 mA) applications involving the use of neutrons from accelerators are becoming more prominent.

These include the highly important field of the detection of explosives and other contraband substances. The techniques comprise thermal neutron analysis and prompt gamma-ray detection for the determination of nitrogen, nano-second pulsed fast neutron analysis to monitor the three key elements oxygen, carbon and nitrogen and, more recently, resonance neutron radiography to yield an elemental image in the detection of features in bulk specimens.

5. Conclusions

Analytical applications based on particle accelerators require a multi-disciplinary approach. They are most successful when you have a scientist or scientists who are expert in the analytical technique as well as the field of application. A successful ion beam analysis laboratory requires a number of scientists who are expert analysts and also ideally specialists in other field such as archaeology or surface science or extractive metallurgy or mineralogy or environmental science in which they do their research. A successful accelerator laboratory also requires highly competent technical services and back-up.

In developing countries such a laboratory could be particularly successful if it forms part of an international collaboration. This could have an archaeological or environmental or global climate basis. In this model the developed countries would be willing to collaborate and use a laboratory in a developing country that would be used for a project of mutual concern. One could imagine a project like that on global climate modeling .

An ion beam analysis laboratory can indeed form an important focus of research that is both fruitful and also economically relevant in the context of a particular country's economy. In the U.S.A. and Western Europe this is often in the context of semi-conductor or material science, while in the developing world this could well be in the context of mineralogy or air pollution or dating or global climate studies.

Its success depends on the availability of an adequate infrastructure to maintain and develop the equipment, of multidisciplinary expertise to exploit the many methods and to do research and a carefully worked out and funded programme that is relevant in relation to the needs of the country and the role of the laboratory. In this last respect the most important feature is the assessment of the country's vision and requirements in terms of the context of a "Country Programme Framework".

6. Recommendations

In view of the increasing importance of accelerator based methods for analysis in many different applications, the Consultants Meeting makes the following recommendations:

1. CM recommends that a TECDOC be drawn up based on the information presented at this meeting, with a particular emphasis on the needs of developing countries in the following areas:
    - Materials (including thin films)
    - Earth Sciences (including Environmental Studies)
    - Biology and Medicine
    - Art and Archaeology (Cultural Heritage)

- Other applications (including forensic applications)

The first draft of this document should be completed by the end of October 1998.

2. The agency should organize appropriate courses in accelerator based analysis emphasizing quantitative results, quality control, development of appropriate protocols and good laboratory practice.

3. It is recommended that Coordinated Research Programmes (CRP) should be considered in the following areas:
   - Applications in mineralogy;
   - Links between biogeology and human health (e.g. Medical Geology in association with COGEOENVIRONMENT, the International Union of Geological Sciences (IUGS) Commission on Geological Sciences for Environmental Planning);
   - Applications in aerosol analysis;
   - Applications to insulators such as glasses, ceramics and polymers (e.g. glass corrosion, the leaching of trace elements and also the role of surface coatings and biocompatible surfaces) with emphasis on the analysis of light elements;

4. The IAEA should collaborate with other international organizations, such as COST (Cooperation in Science and Technology) in the European Community, to extend the scope of existing activities in order to prevent duplication. This supports the recommendation of the AGM on the Establishment of Regional Ion Accelerator Centers and User Networks.

5. The IAEA should support scientists from developing countries to attend selected conferences in this field (such as the IBA - ECAART Conference to be held in Dresden in 1999).

6. The IAEA initiative to establish a database of all accelerator analytical laboratories around the world is appreciated. It is recommended that this should be completed as soon as possible. This database should be maintained on an IAEA Web-site. This should include links to IBA laboratories worldwide.

7. The nuclear data compilations of the Agency have proved to be extremely valuable in this field. It is recommended that the charged particle reaction cross-sections data should be extended. Scattering cross-sections should also be extended to the range where nuclear forces become important.

8. The Agency should consider installing its own low energy accelerator at Seibersdorf Laboratories. This could be used for training and to expand the Agency's existing analytical services.

9. There are a number of areas in which accelerator methods of analysis can make a decisive contribution in an international context. In certain of these areas, such as the investigation of world climate modeling or the study of world heritage sites, the establishment of accelerator-based laboratories in developing countries could be of great value. It is recommended that the IAEA should support and promote international cooperation that could lead to the funding of such laboratories.

CONSULTANTS' MEETING ON APPLICATIONS OF ACCELERATOR BASED NUCLEAR ANALYSIS
20-22 JULY 1998
IAEA HEADQUARTERS, ROOM A07

A G E N D A

Monday, 20 July 1998

9:30 - 10:30	Opening formalities Election of Chairperson Discussion and adoption of the Agenda Introduction, background
10:30-11:00	Coffee Break
11:00-12:30	Individual Presentations and discussion
12:30-14:00	Lunch
14:00-15:30	Individual Presentations and discussion (*cont.*)
15:30-16:00	Coffee Break
16:00-17:30	Planning the report

Tuesday, 21 July 1998

9:00-10:30	Continued discussion on the report
10:30-11:00	Coffee Break
11:00-12:30	Drafting the report
12:30-14:00	Lunch
14:00-15:30	Drafting the report (*cont.*)
15:30-16:00	Coffee Break
16:00-18:00	Drafting proposed recommendations

Wednesday, 22 July 1998

9:00 -	Finalizing the draft report Final considerations Closing of the meeting

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