It is well known that fines and ultrafines can cause severe problems in mining and mineral processing. The decrease in the grade of ore combined with the growing demand for mineral products has led to the mining and milling of increasing tonnage or ore. Closely linked with the problem of reduction in the grade of ore is the more serious problem of the decrease in liberation size. A direct consequence of this is, of course, an increase in the need for fine grinding and a need for techniques for beneficiation of fines. We must note at this point that technology for beneficiating ultrafine and colloidal mineral matters has, for all practical purposes, yet to be developed. There are a number of problems in this regard and there are a number of solutions appearing on the horizon. First, with respect to grinding. In as much as comminution is the most energy consuming operation in mineral processing, every effort has to be directed at reducing the total energy consumption and for this we have to devise methods by which intergranular rather than the usual indiscriminate intragranular, fracture can be produced. And for that, first and foremost, we need to do basic studies to identify means by which applied force can be focused at the grain boundaries where the force is needed. There is also considerable opportunity to make use of beneficial effects that grinding aids can produce in enhancing liberation processes. Today there is hardly any work going on any where to understand what precisely these grinding aids do and why.

Of course once particles are produced, in the mineral processing business, one has to classify them and one should also characterize them. A main problem here is that in the ultrafine and colloidal size range, there is often considerable inconsistency between results obtained using different measurement techniques. Also, it is important to recognize that in addition to the properties such as size. and porosity that are measured, for ultra fines and colloids since
surface forces will start to predominate over all the other forces, it is essential to determine surface chemical composition and surface mineralogical heterogeneity if one is to do meaningful research with such fines.

After the grinding and characterization comes the most critical step in a processing flowsheet: viz the beneficiation itself. And here we find that we do not have efficient techniques or even sufficient basic understanding of the behaviour of fines and ultrafines for developing such technology. Most conventional mineral processing techniques fail in the sub-sieve size range. For example, phosphates are not floated below 150 mesh efficiently and yet the minus 150 mesh fraction contains one third of the phosphate and a number of accessory elements as uranium. Equally serious problems exist also in the processing of cassiterite, taconite and pentlandite ores. Clearly it would appear prudent to try to understand the reasons for the existence for the lower size limit. We need to establish whether these reasons are intrinsic to the process and thus inviolable. It does not appear that we are near intrinsic limits in this separation process since we know that even particles as small as ions can be floated selectively even though under different aeration and agitation conditions. The reasons for the current limits are not completely understood. In the case of gravity it has been suggested that in the fine size range, particles can begin to lose their identity and thus act as fluids. Under such conditions, separation on the basis of specific gravity difference alone becomes nearly impossible. However, it is to be noted that even macro-molecules can be separated using ultracentrifuges. A more important reason for the size limit might be the interference between transport and separation functions in a separator. Then the key for extending the gravity techniques to lower size limit might be design of devices which will produce minimum interference between separation and transportation. It will be most useful to determine what other forces such as centrifugal force can produce differences in positions taken up by different particles and thus extend the operating range of these techniques. Similarly, it can also be important to identify the properties of the fluid that would help in producing better control of fluid drag forces and thereby better separation. Now, in the case of flotation, flocculation and such techniques, the problem results from a number of contributing factors that are not always mutually exclusive. They include factors such as surface area due to fine size as well as low mass; but in addition a major factor that has not been considered is the mineralogical
alterations and chemical alterations such as oxidation that are particularly serious for sulfide fines. Also important in determining adhesion during collision might be change in rugosity which is significant for haematite. If flotation of fines is poor because it is too small, indeed this would suggest that all one needs to do is subject it to selective flocculation. On the other hand, if it is dependent on collision and adhesion during collision, the remedy lies evidently in developing such techniques as dissolved air flotation where the bubbles are generated on the particles selectively. To my knowledge, there has been, however, no basic study of the potential or mechanisms of such techniques. Based on the above considerations, one can examine the applicability of a few techniques that appear to have some potential for the beneficiation of fines.

First, it might be possible to extend flotation to fine size range by developing flotation reagents that can selectively adsorb and this can be done by incorporating groups that can chemisorb or chelate with metals. One can also enhance chemisorption by increasing reagentizing temperature.

If the decrease in efficiency of separation is due to such factors as lower collision and adhesion rate of fines, the obvious solution is presegregation of the fines before flotation. The process of selective flocculation holds tremendous potential when it is accompanied by flotation, elutriation etc. However, various problems existing both at basic and applied levels will have to be solved before this potential can be fully realized. A major problem in this regard is that most of the currently available long chain polymers are bulk flocculants and lack the desired specificity. Specificity can be induced by incorporating active groups into the polymers. However, for most ores, selective flocculation is not easily achieved even under conditions when excellent selectivity is expected. Evidently, we should investigate the nature of interactions between different minerals that are responsible for such behaviour. In this regard, an analysis of various reagents and solution conditions that have been selected for selective flocculation of a taconite ore is very rewarding.

Carrier flotation or ultraflotation involves flotation of ultrafine anatase impurity from clay using an auxiliary material such as calcite. Even though this technique has been used on a commercial scale for almost 20 years, it has not
been successfully used in beneficiating any other ore. Why? Does it work only for clay?

Other potential aggregation processes that we need to look into are spherical agglomeration and emulsion flotation. It has been pointed out by several workers that fines can be collected more easily by oil droplets and bubbles finer than those generated in conventional flotation cells. Techniques that can yield fine bubbles include vacuum flotation, pressure release flotation and electroflotation. None of the above techniques again has, however, been used so far, to my knowledge, on a commercial scale for the processing of mineral fines. Also there are a number of fundamental questions to be answered, here too. For example, why are smaller bubbles more effective in floating fines and what is the role of increased capillary pressure in the smaller bubbles? Again, how does the shape of particles affect the attachment to fine bubbles under turbulent conditions? What is the relationship of particle and bubble size to scale of turbulence normally encountered? And how can you control cell geometry for optimum turbulence? What causes strong flocculation observed in agglomeration flotation? Is oil in fact more efficient at capturing fine particles selectively than air? And if so, why? I believe that a full understanding of such problems can assist in the solution of the practical problems encountered in flotation in general.

Use of differences in magnetic, electrostatic and electrophoretic properties have been attempted by various workers for beneficiation purposes. Both low and high intensity wet magnetic separators have been reportedly used for separation in the sub-sieve size range, the former for treating -325 mesh magnetic taconites and the latter mainly for purification of -2 microns kaolin and for removal of pyrite and ash from fine coal in water slurry. Commercial application of high gradient magnetic separation has been limited so far, to my knowledge, to the beneficiation of kaolin. Use of extraneous agents to treat the ore to generate areas of higher magnetic susceptibility might possibly extend the application of this technique. Another potential area for development here is the use of superconducting magnets. Problems exist here due to the necessity for washing the matrix intermittently without having to switch the magnet off.

Dewatering of mineral slimes and sludges is another serious problem facing the mining industry in various parts of the world. For example, filtration of the
product obtained after selective flocculation was the major technical problem, faced during the recent commercial development of this process. In yet another area, the problems caused by millions of tons of phosphatic slime is notorious. Similar problems exist also in the treatment of coal slimes, red mud etc. There is a definite need here for determining the causes for the pertinacious behaviour of slime-sized particles in suspensions and for developing economical processes for dewatering the slimes.

In summary, the treatment of mineral fines is a critical problem of increasing magnitude and is being recognised so. Even though several techniques can be seen on the horizon for the concentration of such fines, a number of major problems will have to be solved before they can become commercially successful to any significant extent. It is important to recognize that solution of these problems is dependent to a large measure also on a full understanding of the fundamental behaviour of fine particle systems, which can best be achieved. I believe, by collaborative work by scientists and engineers in various disciplines exposed to problems in different parts of the world.