What is intercalation and exfoliation of clay?

Clay is a mineral, naturally occurring in abundance, belonging to phyllosilicate category. Chemically it consists of aluminium silicate as a principal component along with variety of other metals like magnesium, calcium, potassium and varying level of water molecules.
Atomic configuration of clays consists of alternating ‘sheets’ of tetrahedral SiO4 and octahedral AlO6 units formed by oxygen sharing as depicted in Figure 1.

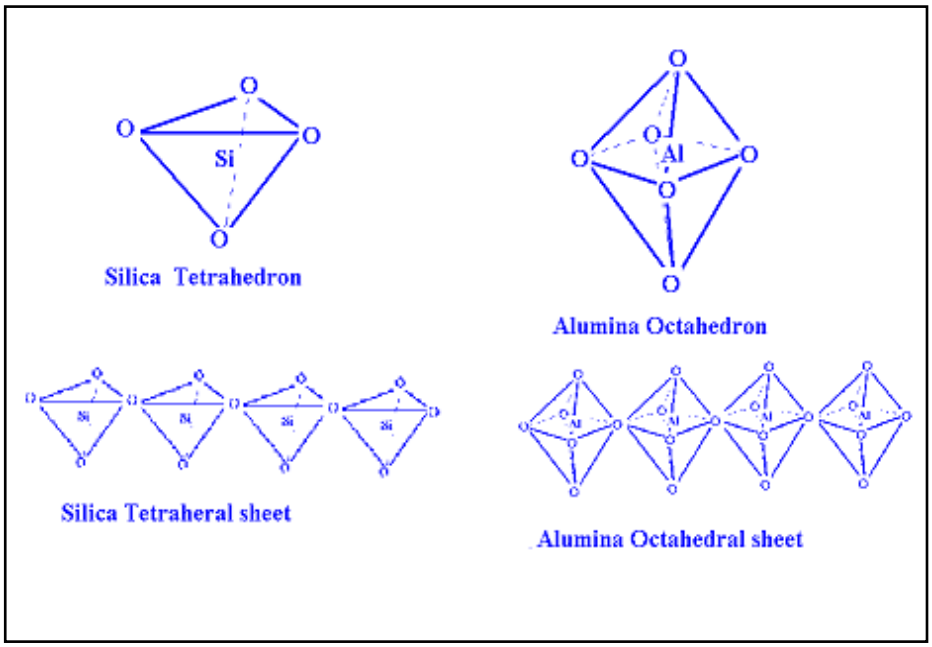

Fig 1: Silica tetrahedral and alumina octahedral sheets formed through oxygen sharing

Combination of such sheets through chemical bonding produces physically distinct entities called ‘layers’ as shown in Figure 2. If one layer comprises only one sheet each of silica and alumina, the clay is termed as 1:1 or T-O (Tetrahedron-Octahedron) clay. Kaolin is a major example of 1:1 clay. Many layers of such 1:1 clay are stacked together through strong hydrogen bonds.

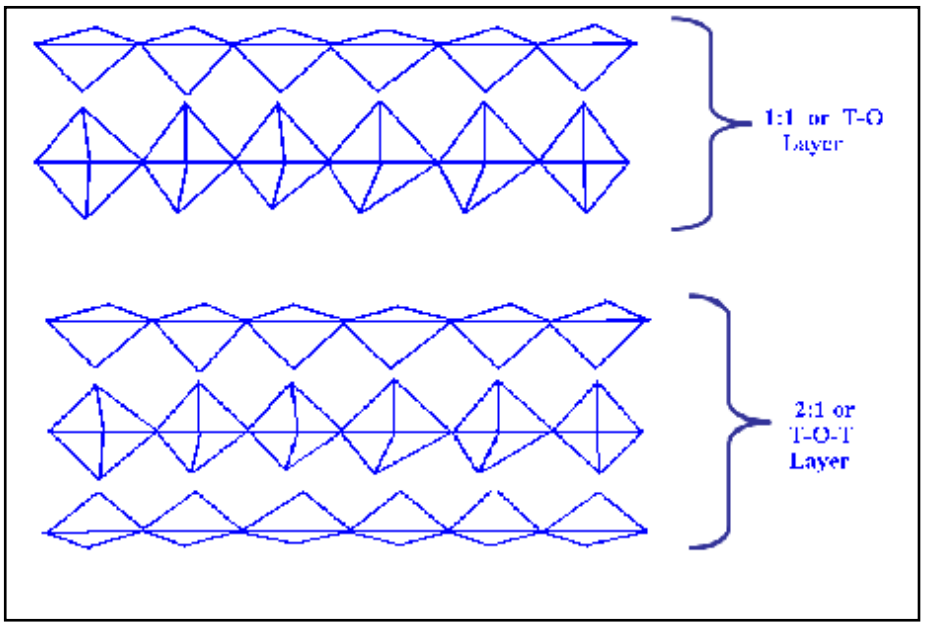

Fig 2: T-O (1:1) & T-O-T (2:1) Types of layers

If one layer is made up of three sheets, silica-alumina-silica, in a sandwich like formation, the resultant clay is called as 2:1 or T-O-T clay. The stacking of such 2:1 layers takes place via van der Waal's forces. There is a gap of about 1 nm between the layers which is sometimes referred to as 'gallery'. Cations like sodium, magnesium, calcium, lithium reside in this region. Smectite clays are 2:1 type, comprising montmorrilonite, hectorite and saponite. These clays are amenable to cation exchange and delayering by expansion of the gallery. It is this nanoscale interlayer gallery which distinguishes these clays from the other minerals. This enables manipulation of clays into nanomaterials as shown in Figure 3.

The gallery in 2:1 type of clays provides the site for following three processes:

- Hydrophobic modification: The cations residing between the layers are exchangeable with quaternary ammonium ions like cetyl-trialkyl-ammonium or cetyl-vinyl-dilakyl ammonium. This process converts the hydrophilic surface of the layer into a hydrophobic one thereby improving the compatibility of nanoclay into polymer matrix. Presence of a polymerizable

group like vinyl, on the surface, facilitates encapsulation by a polymer by in-situ polymerization.

- Intercalation: This is a physical process by which a macromolecule like a dye or polymer is 'inserted 'in the gallery. Such a molecule is flanked by two clay layers and is immobilized and shielded. Width of the gallery is however not much affected during intercalation.
- Exfoliation: This is a delaminating process wherein the gallery is expanded from its normal size of 1 nm to about 20 nm or higher. Thus there is a clear disruption of the layers which get spatially separated apart bringing about nanoscale dispersion in the polymer matrix. Thus exfoliated clays represent true nanomaterials.

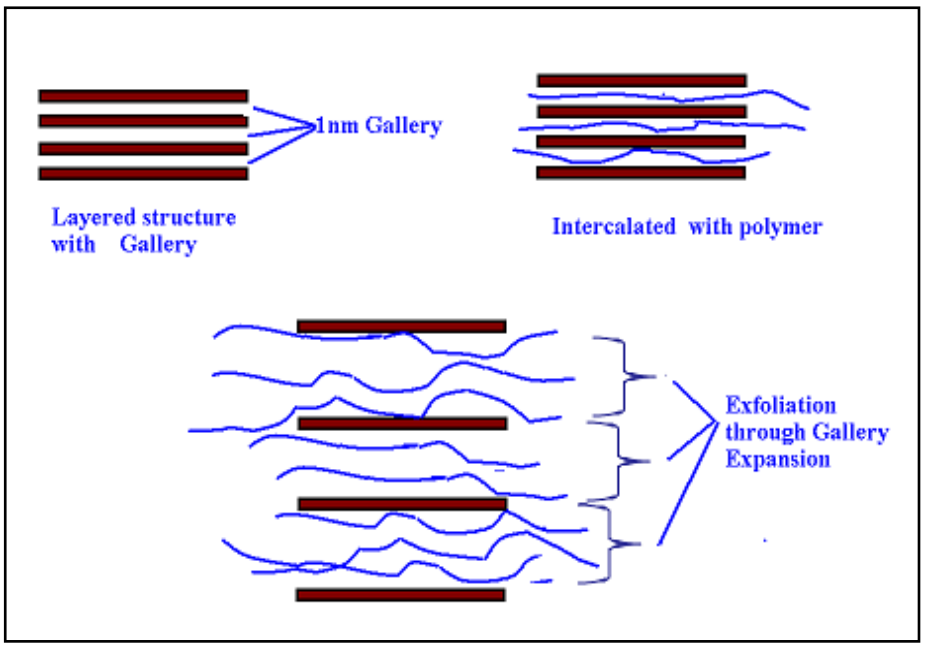

Fig 3: Interlayer gallery, intercalation & exfoliation

Intercalation and exfoliation of the clays can be accomplished by adsorption of the molecules of the chosen polymer from its solution or a melt. In situ polymerization in presence of the clay particles is also used for preparation of intercalated/exfoliated nanoclay composites.