

V MECHANISMS CONTROLLING COMPRESSIBILITY OF CLAYS

1. BACKGROUND

1.1 Definition

- Compressibility refers to the location of the virgin compression line (VCL) for increasing σ'_{vc} and amount of swelling during decrease in σ'_{vc}

1.2 Importance of Initial Fabric

- The starting point of the VCL is governed by the initial fabric of the clay

2) Clay Fabric has two components

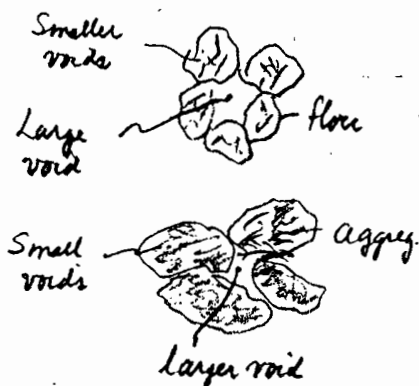
- Orientation of "particles": Flocculated = edge-to-face orientation
(2 extremes) Dispersed = more-or-less parallel orient.

(2) Distribution and make-up of "particles":

- Particle = one solid particle (e.g. kaolinite)

vs. domains = several parallel particles bonded together with 2d spacing of $\approx 10\text{\AA}$
(e.g. Ca montmorillonite)

- Distribution = uniform \rightarrow \approx constant size of void space



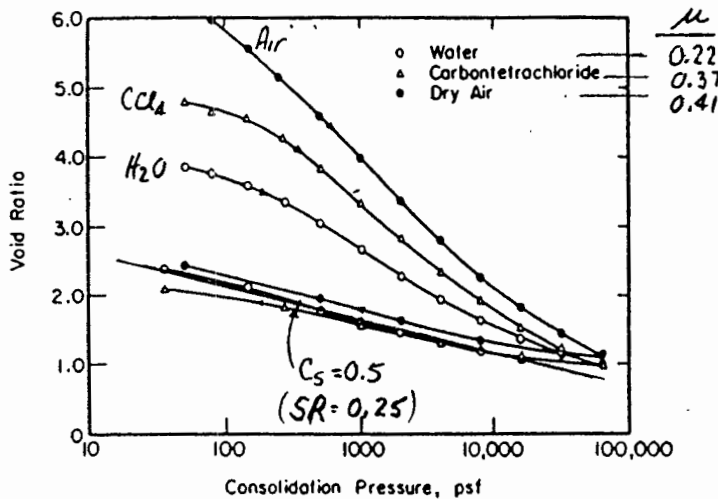
vs. flocs = groups of particles that "stick" together w/ large interfloc voids

vs. aggregates = dense group of particles that are strongly bonded (e.g. due to cementation, $\bar{\sigma}_a > \bar{\sigma}_r$, etc.)

NOTE: Flocs often form during sedimentation, whereas aggregates usually form during drying (especially in oven) and shatter to eliminate when remold soil without very special preparation (low NaCl, mixing, fractionate, etc.)

1.3 Two Models of Clay Compressibility

- 1) MECHANICAL (M) = physical interaction of particles with $\sigma' = \bar{\sigma} \cdot a_c$
 $= (\bar{\sigma}_r - \bar{\sigma}_a) a_c$, where compressibility (and strength behavior) controlled by initial fabric, rigidity of individual "particles" and coefficient of friction (μ) between "particles". Note: "particle" may be aggregate
 - Occurs in clays (and sands, of course) with low effective surface area (ESA), resulting ^{from} large "particle" thickness (t) and often low diameter/thickness ratio (d/t)
 - Elastic deformation (bending) of platy particles becomes more important with increasing d/t
 - Surface chemistry (adsorption of pore fluid) affects friction/adhesion characteristics at contacts between particles
 - At particle contacts, $2d < 20\text{\AA}$; usually with mineral-mineral contact



Example of purely "mechanical" behavior, i.e. $\sigma' = \bar{\sigma} \cdot a_c$ with stiff Elastic Plates

FIG. 1.—ONE-DIMENSIONAL CONSOLIDATION CURVES FOR GROUND MUSCOVITE

In Olson & Mesri (1970) using data from Horn

U of I PhD thesis circa 1960. Estimated $d/t = 20-50 \rightarrow$ very high swelling soil with low SSA

NOTE: $SSA(m^2/g) = 3700 (\frac{2}{t} + \frac{4}{d})$ for particular plates with $G_s = 2.7$ and t, d in \AA



2) PHYSICO-CHEMICAL (PC) = physical interaction of particles with $\sigma' = (R-A)$, where $R = f(P_r)$ & $A = \text{van der Waals}$

- Can achieve with specially prepared Na Montmorillonite (Part VI, 1.1)
- Can be important during swelling of clays with high ESA (small t) when pore fluid \rightarrow high P_r
- Also can be important factor affecting initial fabric of most sedimentary clays with reasonable large ESA

3) M & PC models represent two extremes and neither can fully explain clay behavior.

- Chemistry of pore fluid affects behavior at contacts for M
- " " " " " " " " initial fabric for both PC & M
- Never obtain $\sigma' = R-A$ in natural clays

4) Characterization of platy particles ($d = \text{dia.}$, $t = \text{thickness}$)

$t(A)$	Mineral	Typical d/t	Description
?	Mica	up to 20-50	Very stiff elastic plates
≥ 1000	Kaolinite	$\leq 5-10$	Very rigid, thick plates
$\geq 100?$	Illite	up to 50?	Fairly flexible elastic plates
Down to 10	Na Mont.	$\geq 100-500$	Very thin, highly flexible plates
$>> 10$	Cu Mont.	Much less	Much thicker & less flexible

$1 \mu m = 10^4 \text{ \AA}$



2/6/01

2. COMPONENTS OF VOLUME CHANGE

- See Table II (p 5) for 4 components that occur during virgin compression and 2 components during swelling
- Attempt made to differentiate between those caused by Mechanical (M) vs Physico-Chemical (PC) models

3. EXAMPLES OF FACTORS AFFECTING INITIAL FABRIC

- 1) See Fig. V (p 6) for variation in initial void ratio at $\sigma'_{vc} = 100 \text{ psf}$ during virgin compression of four clay minerals (S, I, K & Mica) with six different pore fluids (shown in order of decreasing DL thickness and/or surface-fluid attraction).
Note that all systems have a flocculated "particle orientation" (to Δ degrees)
- 2) Changes in the pore fluid affect:
 - R vs $A \rightarrow \Delta$ particle orientation
 - $\bar{\sigma}_r$ vs $\bar{\sigma}_a \rightarrow \Delta$ "coef. of friction"
 - ESA $\rightarrow \Delta$ importance of PC vs M behavior
- 3) Discuss relative values of S & I vs K & M as change pore fluid from low $H_{22}Co \rightarrow CCl_4$ & air

Table V Components of Volume Change for Clays

Component of Volume Change	On VCL		Mechanism	Comments
	+ $\Delta\sigma'_{vc}$	- $\Delta\sigma'_{vc}$		
1. Elastic deformation of platy particles (stored elastic energy)	Bending	Unbending	M	Increasing importance with incr. d/t (incr. ESA)
2. Change in closest spacing	Displaced	Re-enters	M	More important at high dielectric constant (D) fluid
a) $2d < 20\text{\AA}$ (Contacts)				Only important for high ESA or during sedimentation
b) $2d > 20\text{\AA}$ (DL)	Double Layer Compress	Layer Expands	PC	
3. Particle reorientation	Particles more parallel	NO	M	Both friction (min. min. contact) and adhesion ($\bar{\sigma}_a > \bar{\sigma}_f$)
a) Sliding at contacts	" " "	NO	PC	Only important for high ESA with $R > A$?
b) More parallel fabric	" " "	NO		
4. Crushing	Reduce large voids	NO	M	Can occur at all σ' levels
a) Floccs and aggregates	" " "	NO	PC?	Only at v. low σ' levels?
b) Floccs	" " "	NO		

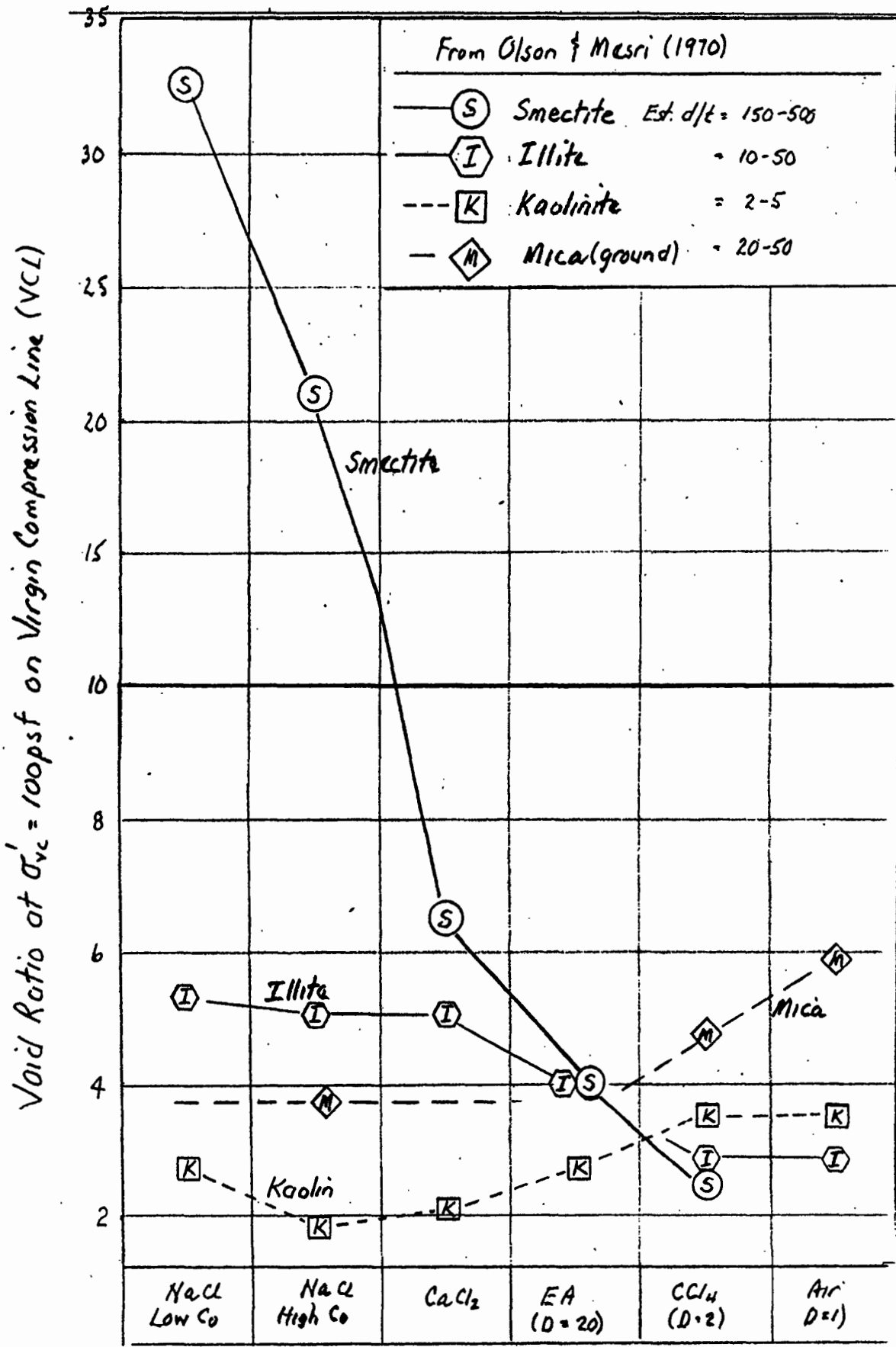


Fig V Effect of Clay Mineral & Pore Fluid on Initial VCL