5. Joint blocks

- Joint blocks: rock blocks determined entirely by joint planes without free surfaces
  - Generally do not draw any significant concern in rock mechanics literature because they are hidden within rock mass.
  - Affect the size and shape of blasted rock materials (Fig.5.2, 5.3).
  - Affected by orientation, spacing and extent of each joint set.
  - Difference with free plane-bearing blocks: more chances to have parallel joints as boundary planes.

- Intuitively derived principles in block occurrence
  - Blocks made by less joints are more likely to occur (Fig. 5.5).
    Ex) 1100 vs. 1120 (2D)
  - Blocks with parallel joints are more likely than those with non-parallel joins.
    Ex) 3322 > 3323 > 1120 (2D)

1) Joint blocks in 2D

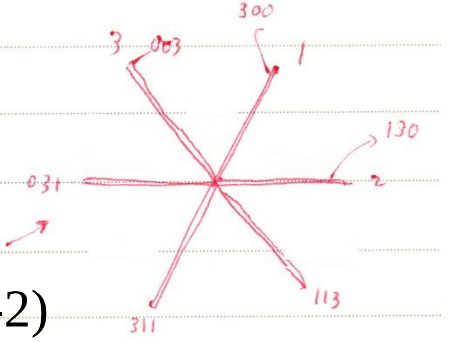
- Joint blocks with no repeated joints (Fig.5.7, 5.8)

  - No. of all JPs: 2^n
  - No. of non-empty JPs: $2n$ ($n \geq 1$)
  - No. of empty JPs (finite JB): $2^n - 2n$

- Joint blocks with one repeated joint set (Fig.5.9)

  - No. of all JPs: 2^{n-1}
  - No. of non-empty JPs: 2
  - No. of empty JPs (finite JB): $2^{n-1}-2$

    when the repeated joint is selected randomly: $n(2^{n-1}-2)$



1) Joint blocks in 2D

- Joint blocks with two or more repeated joint sets (Fig.5.11)

  - No. of all JPs: 2^{n-m}

  - No. of non-empty JPs: 0

  - No. of empty JPs (finite JB): 2^{n-m}

    when the repeated joint is selected randomly: ${}_nC_m\ 2^{n-m} = n!/[(n-m)!m!]\ 2^{n-m}$

2) Joint blocks in 3D

- Joint blocks with no repeated joints (Fig.5.16)

n	No. of non-empty JPs
1	2
≥ 2	2(n-1) JPs are added
n	$2+\sum_{i=2}^{n} 2(i-1) = 2-2(n-1)+(2+n)(n-1)$
	$= n^2 - n + 2$

- Joint blocks with one repeated joint set (Fig.5.17)

  - No. of all JPs: 2^{n-1}

  - No. of non-empty JPs: 2(n-1)

  - No. of empty JPs (finite JB): 2^{n-1} -2(n-1)

  when the repeated joint is selected randomly: $n(2^{n-1} - 2(n-1))$

2) Joint blocks in 3D

- Joint blocks with two repeated joint sets (Fig.5.18)
  - No. of all JPs: 2^{n-2}
  - No. of non-empty JPs: 2
  - No. of empty JPs (finite JB): 2^{n-2} -2

  when the repeated joint is selected randomly: ${}_nC_2(2^{n-2}-2)= n(n-1)(2^{n-2}-2)/2$

- Joint blocks with three or more repeated joint sets (Fig.5.19, 20)
  - No. of all JPs: 2^{n-m}
  - No. of non-empty JPs: 0
  - No. of empty JPs (finite JB): 2^{n-m}

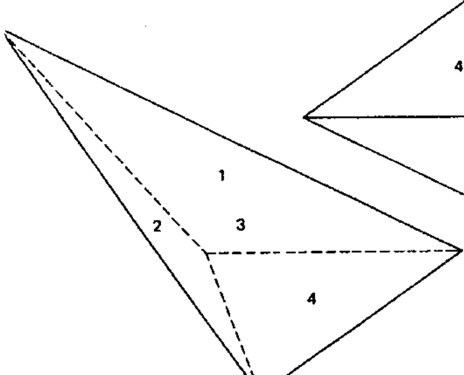
  when the repeated joint is selected randomly: ${}_nC_m2^{n-m}$

3) Stereographic projection solution for joint blocks

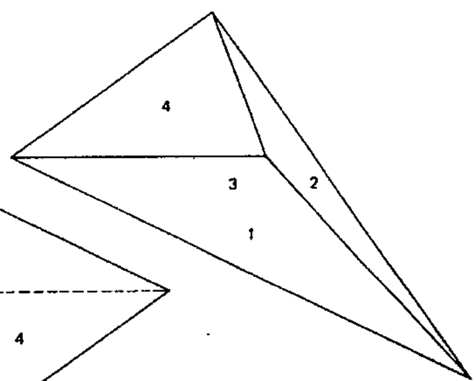
- Finite joint blocks with no repeated joint sets

TABLE 5.3

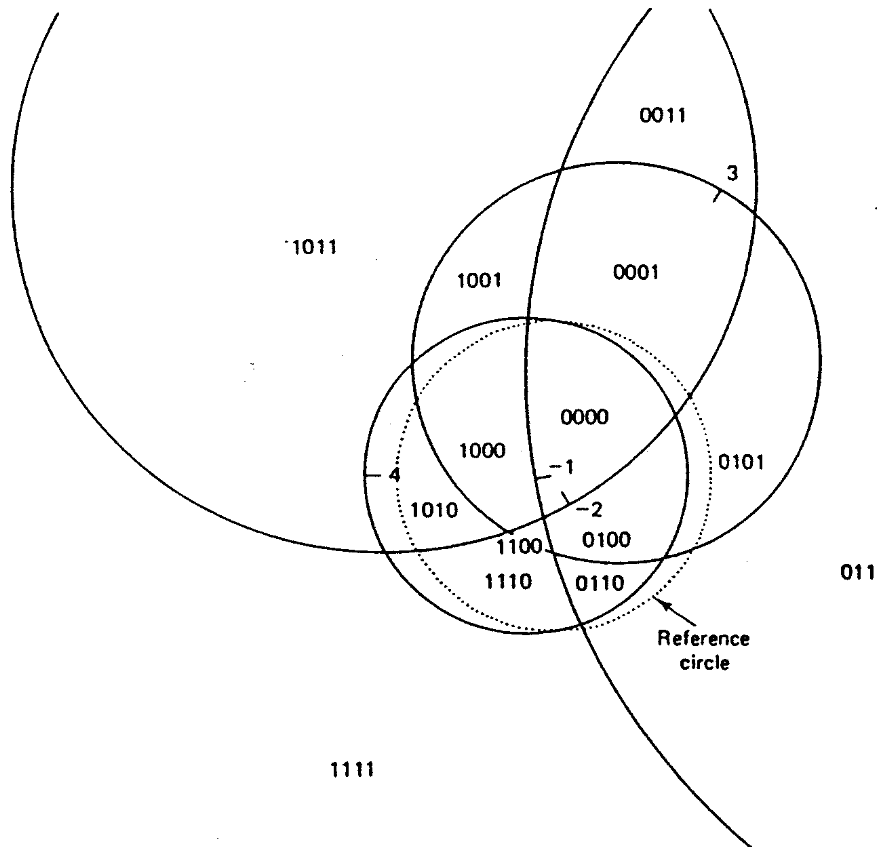
Set	Dip, α (deg)	Dip Direction, β (deg)
1	75	80
2	65	330
3	40	30
4	10	270



(b)

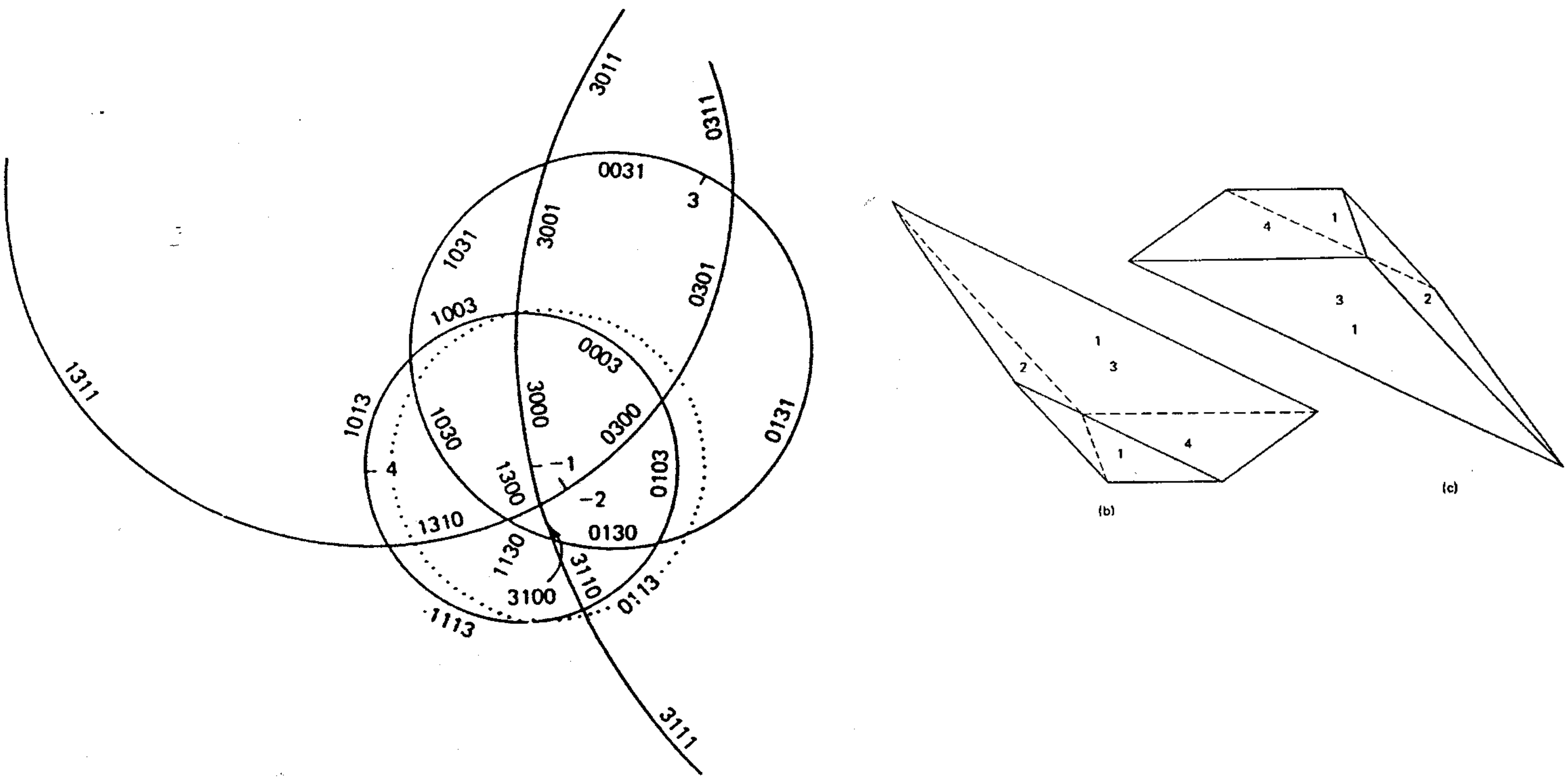


(c)



3) Stereographic projection solution for joint blocks

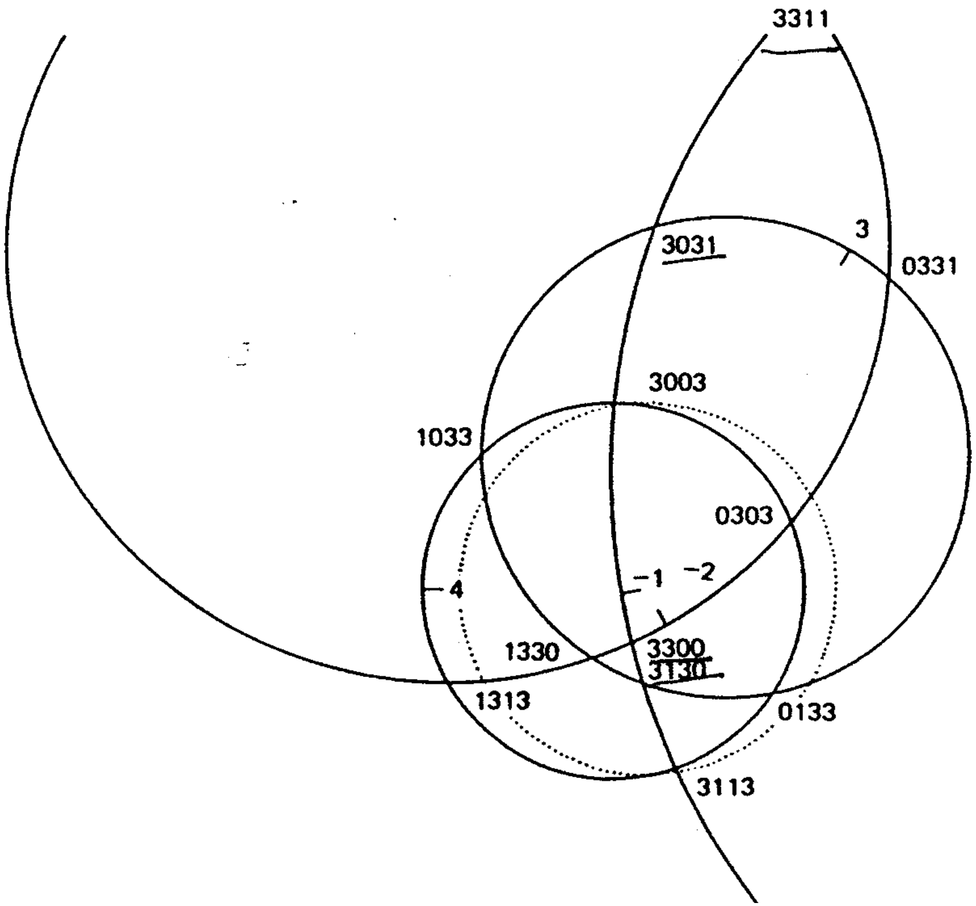
- Finite joint blocks with one repeated joint set

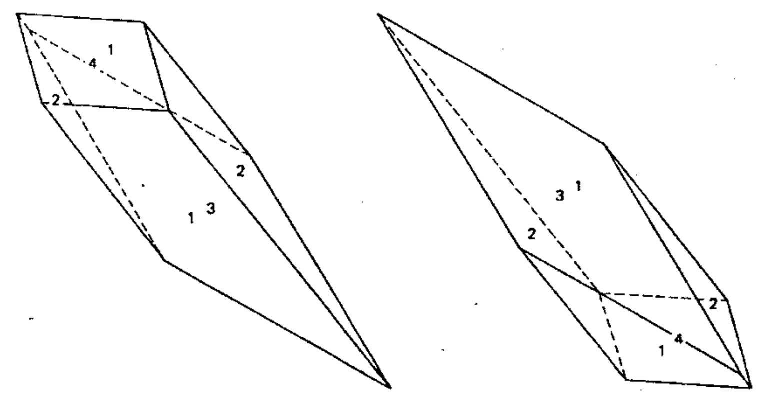


(a) (b) (c)

3) Stereographic projection solution for joint blocks

- Finite joint blocks with two repeated joint sets





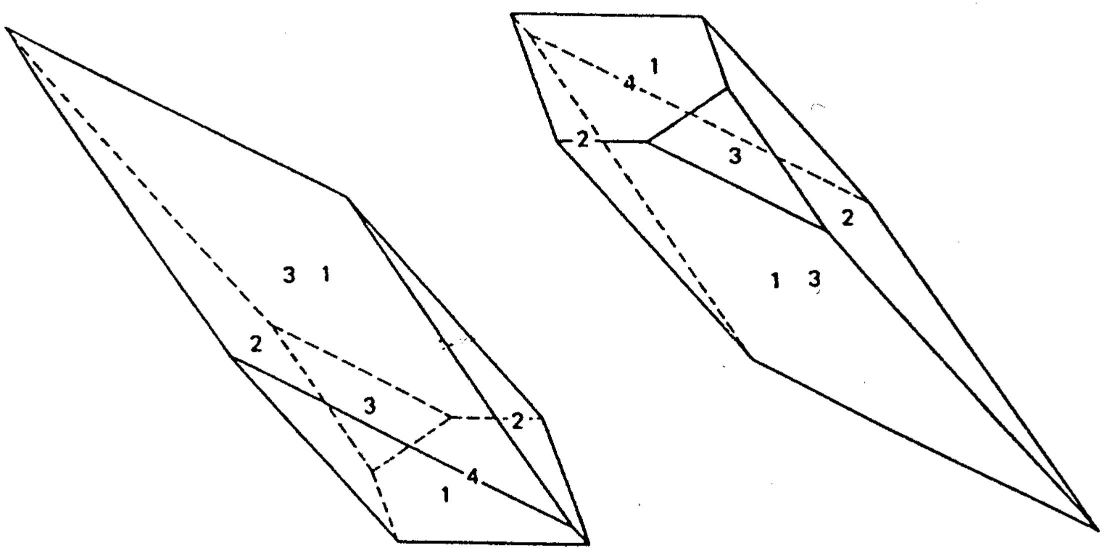
(b) (c)

3) Stereographic projection solution for joint blocks

- Finite joint blocks with three or more repeated joint sets

TABLE 5.6 Empty Joint Pyramids with Three Repeated Joint Sets for the Joint System of Table 5.3

Repeated Joint Sets	Empty Joint Pyramids
2, 3, 4	0333, 1333
1, 3, 4	3033, 3133
1, 2, 4	3303, 3313
1, 2, 3	3330, 3331



(a) (b)

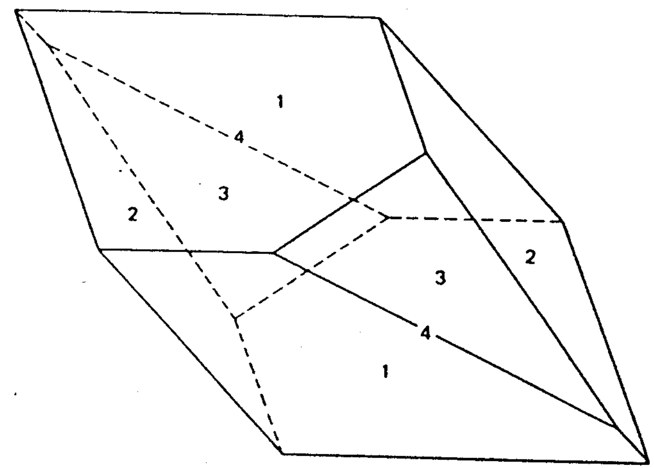


Figure 5.20 Finite block 3333.

4) Computation of emptiness of joint pyramids using vectors

TABLE 5.7

Joint Set	X	Y	Z
1	0.9512	0.1677	0.2588
2	−0.4531	0.7848	0.4226
3	0.3213	0.5566	0.7660
4	−0.1736	0	0.9848

$$0.9512X + 0.1677Y + 0.2588Z \geq 0$$
$$0.4531X - 0.7848Y - 0.4226Z \geq 0$$
$$0.3213X + 0.5566Y + 0.7660Z \geq 0$$
$$-0.1736X + 0.9848Z \geq 0$$

- With no repeated joint sets: 0100 (p.148)

1) Calculate normal vectors of joints.
2) Define JP inequalities according to JP (= BP) code.
3) Calculate direction vectors of joint intersections:
$$\pm\vec{I}_{12},\ \pm\vec{I}_{13},\ \pm\vec{I}_{14},\ \pm\vec{I}_{23},\ \pm\vec{I}_{24},\ \pm\vec{I}_{34}$$
4) Check whether any intersection vector satisfies the JP inequalities.
5) If the JP inequalities are not satisfied for any intersection vectors the joint block is finite.

4) Computation of emptiness of joint pyramids using vectors

- With one repeated joint set: 1310
  - Follow the same procedure as in the case of no repeated joints.
    c.f. JP of the repeated joint should be expressed by an equality.

$$
\begin{aligned}
-0.9512X - 0.1677Y - 0.2588Z &\geq 0 \\
-0.4531X + 0.7848Y + 0.4226Z &= 0 \\
-0.3213X - 0.5566Y - 0.7660Z &\geq 0 \\
-0.1736X \quad + \quad 0.9848Z &\geq 0
\end{aligned}
$$

Intersection vectors to check:
$\pm\vec{I}_{12},\ \pm\vec{I}_{23},\ \pm\vec{I}_{24}$

- With two repeated joint sets: 3031
  - Follow the same procedure as in the case of one repeated joint.

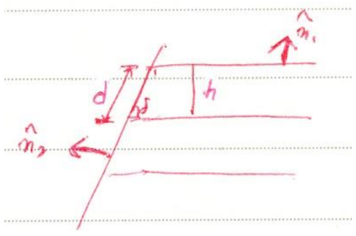
$$
\begin{aligned}
0.9512X + 0.1677Y + 0.2588Z &= 0 \\
-0.4531X + 0.7848Y + 0.4226Z &\geq 0 \\
0.3213X + 0.5566Y + 0.7660Z &= 0 \\
+0.1736X \quad - \quad 0.9848Z &\geq 0
\end{aligned}
$$

Intersection vectors to check: $\pm\vec{I}_{13}$

5) Application of block theory: an example

- Joint spacing (true & apparent spacing)

$$h = d \sin \delta, \quad \cos \delta = \left| \hat{n}_1 \cdot \hat{n}_2 \right|$$



- Constructing a trace map in any section plane

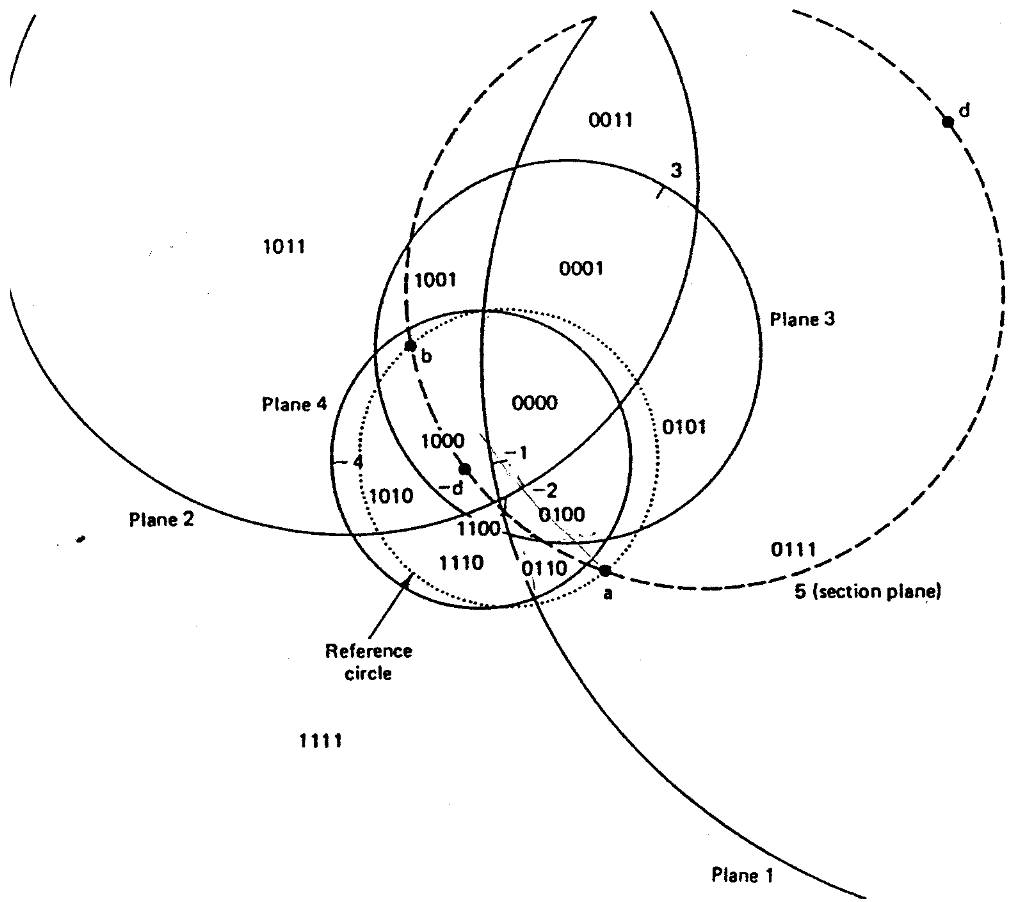
Joint trace: $\vec{I}_{12} = \hat{n}_1 \times \hat{n}_2$

'1' denotes joint and '2' denotes rock exposure.

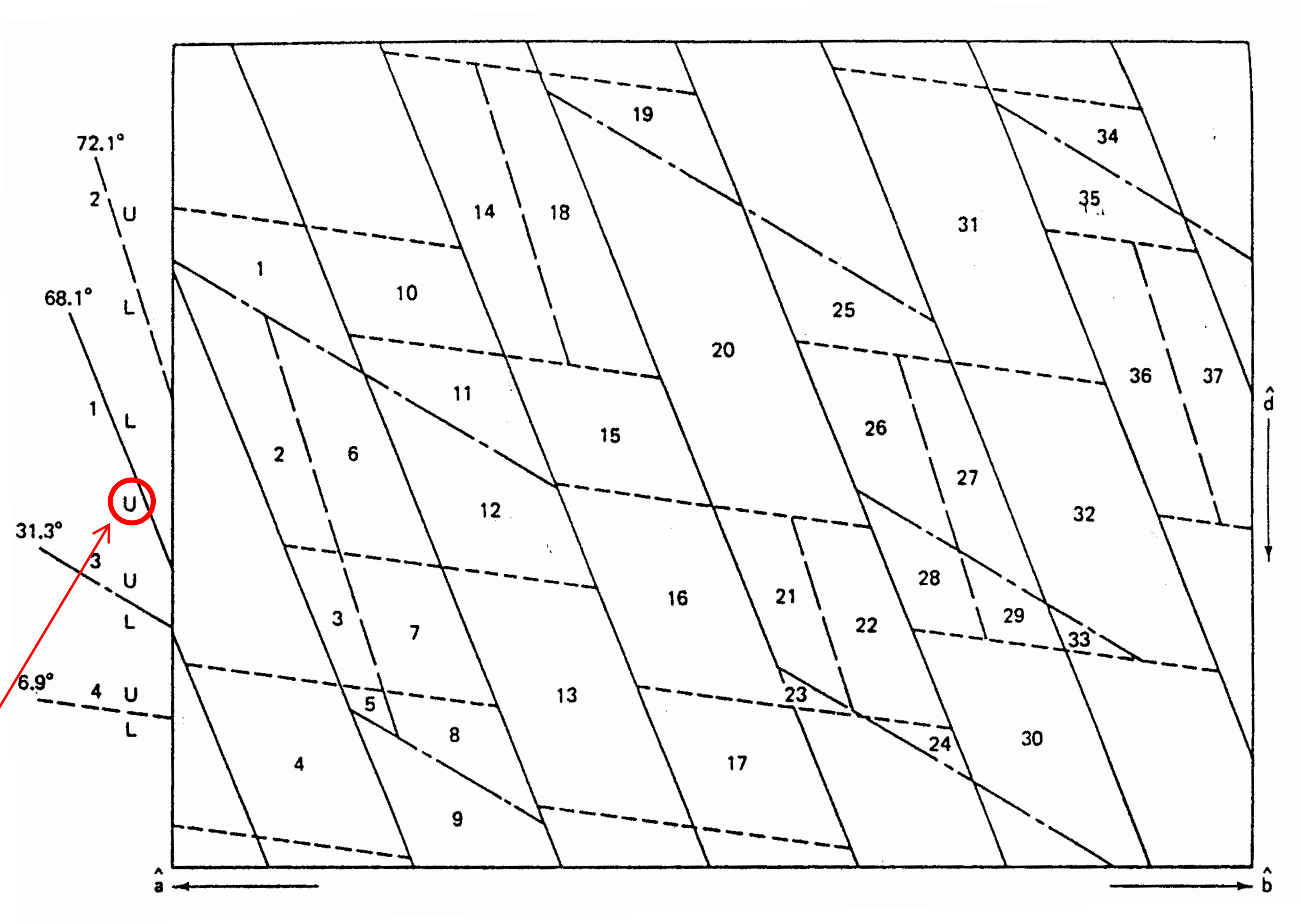
- The ratio of finite to infinite blocks as a rock mass index

5) Application of block theory: an example

- Constructing a trace map in any section plane



5) Application of block theory: an example



This means that dip vector of rock exposure is located inside of the great circle of Jt 1.

5) Application of block theory: an example

- The ratio of finite to infinite blocks as a rock mass index

Complete polygons: 37
Finite joint blocks: 11
Infinite joint blocks: 26
Semi-continuous rock mass – relatively higher powder factor than the case of discontinuous rock mass is required.

Home Work

- Make a computer code that shows block types (tapered, finite & infinite) of rock blocks formed by combination of 4 joints and 1 free plane when the orientation (dip/dip direction) of each joint/free plane is given.