should be located in sites with evidence of status differences among community members. At Paso de la Amada, we have mounting evidence for both high- and low-status households that are contemporary with the ball court^{7–10}. The location and excavation of more early ball courts should help to establish their role in the emergence of social and political complexity.

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New ice outdoes related nets in smallest-ring size

In a recent Letter, Lobban, Finney and Kuhs¹ reported a remarkable new metastable form of ice (ice XII) in the field of stability of ice V and presented an accurate structure determination. The authors state correctly that the topology of the phase is unlike that of any of the known phases of ice. They also state that it “contains a mixture of five- and seven-membered rings of water molecules” which “is interesting, although not unexpected”. This second statement is not completely true; the truth is more interesting and, I believe, unexpected, as is agreed by the authors of ref. 1 (personal communication). The structure contains only seven- and eight-membered rings and is the first example of a 4-connected net of this type.

The 4-connected nets of interest in crystal chemistry can all be realized as 4-coordinated sphere packings, in which the sphere centres correspond to the vertices of the net and the sphere contacts correspond

Figure 1 Nets projected down c with numbers giving elevations in multiples of $c/8$. Left, the ice XII net. Links between vertices are shown as lines, pairs of links up and down as double lines, and links between vertices in adjoining cells as broken lines (for example, a line between vertex at elevation 6 and one at elevation 1 is really a link between vertices at elevations -2 and 1, or at 6 and 9). The dashed square outlines a unit cell. Right, a second net with the same symmetry as that of ice XII but of lower density.

to edges. This ensures that each vertex has exactly four equidistant nearest neighbours. In practice, a further restriction is useful²; in the conformation of maximum volume subject to the constraint of equal edges, the structure should remain 4-coordinated.

The net of the new ice structure fits these criteria, and I give coordinates for maximum volume and equal (unit) edge length. The symmetry is $I\bar{4}2d$ with $a = 2.988$, $c = 1.424$, $c/a = 0.477$. The vertices are of two kinds: A in $4a, 0,0,0 \dots$ and B in $8d, x,1/4,1/8 \dots$ with $x = 0.3675$. This is close to the conformation ($c/a = 0.485$, $x = 0.3643$) found in the real material¹.

The vertex symbols³, which give the number and kind of smallest rings contained in each angle, are for A: $7_2 \cdot 7_2 \cdot 7_2 \cdot 8_4 \cdot 8_4$ and for B: $7_3 \cdot 7_3 \cdot 7_3 \cdot 8_4 \cdot 8_4$. It turns out that every angle containing 7-rings also contains two 8-rings, and the total ring count for the unit cell is sixteen 7-rings and twenty-four 8-rings.

Figure 1 (left) shows the net projected down c . It should be clear that there are no 5-rings. I find this structure remarkable because every other known 4-connected net of interest in crystal chemistry contains smallest rings that are 6-rings or smaller. This is true for all the 130 or so zeolite structures; indeed, it is true for all 400 or so individual vertices of these structures.⁴

It is also true for all my collection of more than 200 uninodal and binodal nets, most of which occur in one or more contexts in crystal chemistry. From a study of such structures, it was concluded⁵ that “a tetrahedral framework whose smallest rings are 7-membered or more will probably not be possible”.

A net has been described³ with only 7-rings, but this is an exceptional structure that cannot be realized as a 4-coordinated sphere packing and with one angle that lacks

rings. It is not likely to serve as a framework for structures such as ices and aluminosilicates.

The new structure (in the maximum-volume form given above) is one of the densest 4-connected nets in known crystal structures (I exclude intergrowths of two or more nets such as are found in some dense forms of ice). For unit edge length, the number of vertices per unit volume is $r = 0.944$. This might be compared with $r = 0.845$ for coesite (the densest 4-connected silica net) and $r = 0.750$ for quartz.

The most nearly comparable structure is that of ice IV (ref. 6), which also occurs metastably in the ice V stability field and for which I find $r = 0.971$ in the maximum-volume form. The vertex symbols for the two vertices (which occur in the ratio 1:3) in this structure are $6_2 \cdot 8_2 \cdot 6_2 \cdot 8_2 \cdot 6_2$ and $6 \cdot 6_2 \cdot 6 \cdot 8_3 \cdot 6 \cdot 8_3$ (this structure also contains 10-membered rings).

Another net (Fig. 1, right) that has the same symmetry as that of ice XII but is of lower density ($r = 0.669$) does contain 5- and 7-rings and appears in simulated annealing experiments⁷ as a silicon net in SiO_2 . For this net (again with unit edges), $a = 3.193$, $c = 1.760$, and the vertices are $5 \cdot 5 \cdot 5 \cdot 5 \cdot 8_2 \cdot 8_2$ at $0,0,0$, and $5 \cdot 5 \cdot 5 \cdot 7 \cdot 7 \cdot 7$ at $0.1556, 1/4, 1/8$.

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