What is claimed is:

1. A tree cap assembly (11) for capping a bore (47) of a subsea wellhead assembly (16), the bore (47) having an axis (67), the tree cap assembly (11) comprising:

an annular cage member (41) selectively insertable into the bore (47) and having an interior (45);

a cam element (33) having a portion positioned in the interior (45) and axially movable with respect to the cage member (41);

an annular actuation member (71) positioned between the cage member (41) and the cam element (33);

an annular seal (49) between the cam element (33) and bore (47), that is selectively energized when axially compressed against the actuation member (71) by cam element (3) to form a pressure barrier in the bore (47);

a locking assembly (59) comprising a dog (73) that projects radially outward through a sidewall of the cage member (41) into selective engagement with a groove (57) that circumscribes the bore (47); and

an actuation assembly (11, 103, 123) coupled to the cam element (33) so that when actuated, the actuation assembly (11, 103, 123) moves the cam element (33) axially relative to the annular cage member (41) to compress the seal (49) against the actuation member (71).

2. The tree cap assembly (11) of Claim 1, wherein the cam element (33) comprises:

a stem (35) extending from the bore (47) to the actuation assembly (11, 103, 123) through the interior (45) of the cage member (41);

a medial portion (37) mounted to the stem (35) and having a conical surface (77) that selectively engages the dog (73) to drive the dog (73) into the groove (57); and

a seal carrier portion (39) mounted to the medial portion (37) opposite the stem (35) and configured to carry the annular seal (49) and energize the annular seal (49) in response to axial movement of the cam element (33).

3. The tree cap assembly (11) of Claim 1, the actuation assembly (11, 103, 123) comprising:

a housing (15, 125) having a cavity (23, 129); and

an axially moveable spreader plate (25, 127) positioned in the cavity (23, 129), the spreader plate (25, 127) having a width substantially equivalent to a width of the cavity (23, 129), the cam element (33) coupled to the spreader plate (25, 127) so that axial movement of the spreader plate (25, 127) moves the cam element (33) to compress the annular seal (49) against the actuation member (71); an actuation portion (137) depending from the housing (125), through the cage member (151) and having a lower portion (147) positioned between a lower end (159) of the cage member (151) and the cam element (139); and

wherein the annular actuation member (71) depends from the actuation portion (137).

4. The tree cap assembly (11) of Claim 3, the actuation assembly (11, 123) further comprising a mechanical energizer (27, 131) extending from a wall (29, 133) of the housing (15, 125) disposed proximate to a subsea tree (14) when the tree cap (11, 123) lands on a tree head (13) of the subsea tree (14) to the spreader plate (25, 127), the mechanical energizer (27, 131) configured to exert an axial force on the spreader plate (25, 127) to drive the spreader plate (25, 127) axially upward and to maintain an axial force on the spreader plate (25, 85, 127) to maintain the annular seal (49) in the energized position.

5. The tree cap assembly (11) of Claim 4, the actuation assembly (11) further comprising a hydraulic actuator (17) positioned opposite the mechanical energizer (27) to move the spreader plate (25) axially to compress the mechanical energizer (27) to maintain the seal (49) in the unset position during running and retrieval of the tree cap assembly (11).

6. The tree cap assembly (11) of Claim 1, wherein the actuation assembly (103) comprises:

a housing (83) having a cavity (87) and configured to receive and direct hydraulic pressure;

a hydraulic piston (85) having an actuation surface (113) and a retrieval surface (107), the hydraulic piston (85) positioned in a cavity (87) of the housing (83) and configured to move axially in response to application of hydraulic fluid pressure to the actuation and retrieval surfaces (113, 107);

the cam element (33) coupled to the hydraulic piston (85) so that axial movement of the hydraulic piston (85) moves the cam element (33) to compress the annular seal (49) against the actuation member (71); and

one or more valves (101, 109) actuable to selectively permit application of hydraulic fluid pressure to the actuation and retrieval surfaces (113, 107) of the hydraulic piston (85).

7. The tree cap assembly (11) of Claim 6, wherein the actuation assembly (103) further comprises:

an accumulator (119) to store at least one of hydraulic fluid pressure and gas pressure;

a charge valve (117) in communication with the accumulator (119) to selectively supply at least one of hydraulic fluid pressure and gas pressure to the accumulator (119) and vent at least one of hydraulic fluid pressure and gas pressure from the accumulator (119);

an accumulator valve (121) positioned between the accumulator (119) and the actuation assembly (103) and in communication with the actuation surface (113) of the hydraulic piston (85) to selectively allow communication between the accumulator (119) and the actuation surface (113) of the hydraulic piston (85);

wherein the accumulator (119), the charge valve (117), and the accumulator valve (121) are configured to selectively apply at least one of hydraulic fluid pressure and gas pressure to the actuation surface (113) of the hydraulic piston (85); and

wherein the application of at least one of hydraulic fluid pressure and gas pressure from the accumulator (119) maintains the energization of the seal (49).

8. A tree cap assembly (11) for capping a bore (47) of a subsea wellhead assembly (16), the bore (47) having an axis (67), the tree cap assembly (11) comprising:

an annular cage member (41) selectively insertable into the bore (47) formed in the wellhead assembly (16), the annular cage having an interior (45);

an annular actuation member (71) depending from a lower end (55) of the cage member (41);

a cam element (33) having a portion positioned in the interior (45) of the cage member (41) and axially movable with respect to the cage member (41);

an annular seal (49) between the cam element (33) and an inner surface of the bore (47), the cam element (33) selectively energizing the annular seal (49) by compressing the annular seal (49) axially against the actuation member (71) to form a pressure barrier in the bore (47);

a locking assembly (59) comprising a dog (73) that projects radially outward through a sidewall of the cage member (41) into selective engagement with a groove (57) that circumscribes the bore (47);

a housing (83) having a cavity (87) and configured to receive and direct hydraulic pressure;

a hydraulic piston (85) having an actuation surface (113) and a retrieval surface (107), the hydraulic piston (85) positioned in a cavity (23, 87, 129) of the housing (15, 83, 125) and configured to move axially in response to application of hydraulic fluid pressure to the actuation and retrieval surfaces (113, 107);

the cam element (33) coupled to the hydraulic piston (85) so that axial movement of the hydraulic piston (85) moves the cam element (33) to compress the annular seal (49) against the actuation member (71) by moving the cam element (33) axially relative to the annular cagemember (41);

one or more valves (101, 109) actuable to selectively permit application of hydraulic fluid pressure to the actuation and retrieval surfaces (113, 107) of the hydraulic piston (85).

an accumulator (119) to store at least one of hydraulic fluid pressure and gas pressure;

a charge valve (117) in communication with the accumulator (119) to selectively supply at least one of hydraulic fluid pressure and gas pressure to the accumulator (119) and vent at least one of hydraulic fluid pressure and gas pressure from the accumulator (119);

an accumulator valve (121) positioned between the accumulator (119) and the actuation assembly (103) and in communication with the actuation surface (113) of the hydraulic piston (85) to selectively allow communication between the accumulator (119) and the actuation surface (113) of the hydraulic piston (85);

wherein the accumulator (119), the charge valve (117), and the accumulator valve (121) are configured to selectively apply at least one of hydraulic fluid pressure and gas pressure to the actuation surface (113) of the hydraulic piston (85); and

wherein the application of at least one of hydraulic fluid pressure and gas pressure from the accumulator (119) maintains the energization of the seal (49).

9. The tree cap assembly (11) of Claim 8, wherein the cam element (33) comprises:

a stem (35) extending from the bore (47) to the actuation assembly (11, 103, 123) through the interior (45) of the cage member (41);

a medial portion (37) mounted to the stem (35) and having a conical surface (77) that selectively engages the dog (73) to drive the dog (73) into the groove (57); and

a seal carrier portion (39) mounted to the medial portion (37) opposite the stem (35) and configured to carry the annular seal (49) and energize the annular seal (49) in response to axial movement of the cam element (33).

10. The tree cap assembly (11) of Claim 9, wherein the annular seal (49) comprises a wedge-type cross sectional profile.

11. A method for capping and sealing a subsea tree (14) including a tree head (13), a bore (47) having an axis (67), and a locking groove (57) formed therein, the method comprising:

(a) providing a subsea tree cap (11, 103, 123) having a cam element (33) carrying an annular metal seal (49) having a wedge type profile, the cam element (33) moveable along the axis (67) of the bore (47);

(b) running the subsea tree cap (11, 103, 123) to the subsea tree (14) located proximate to the sea floor (20);

(c) positioning a portion of the cam element (33) in the bore (47) and lowering the subsea tree (11, 103, 123) cap to land on the subsea tree (14); and

(d) moving the cam element (33) axially upward to secure the subsea tree cap (11, 103, 123) to the subsea tree (14) and deformingly engage the annular metal seal (49) to seal to the subsea tree cap (11, 103, 123) and the bore (47) of the subsea tree (14).

12. The method of Claim 11, wherein step (d) further comprises slidingly engaging a medial portion (37) of the cam element (33) having a conical profile (77) against a conical cam surface (75) of an annular dog (73) carried by the subsea tree cap (11, 103, 123) to expand the annular dog (73) radially into the locking groove (57) of the bore (47).

13. The method of Claim 11, wherein step (d) further comprises compressing the annular metal seal (49) between a lower conical portion (53) of the cam element (33) and an actuation member (71) depending from an outer diameter of a cage of the subsea tree cap (11, 103, 123) positioned in the bore (47) of the subsea tree (14); and removing hydraulic pressure from a hydraulic cylinder (17) exerting a downward axial force on the cam element (33), thereby allowing a mechanical energizer (27) coupled to the cam element (33) to exert an upward axial force on the cam element (33).

14. The method of Claim 11, wherein step (d) further comprises supplying hydraulic fluid pressure to a hydraulic piston (85) coupled to the cam element (33) to move the cam element (33) axially upward and releasing gas pressure stored in an accumulator (119) of the subsea tree cap to exert an upward axial force on the cam element (33) that maintains the engagement of the seal (49) to the bore (47).

15. The method of Claim 11, further comprising maintaining an upward axial force on the hydraulic piston (85) to accommodate for thermal expansion and contraction of the subsea tree (14) and creep and stress relaxation of the annular seal (49).

What is claimed is:

1. A tree cap assembly for capping a bore of a subsea wellhead assembly, the bore having an axis, the tree cap assembly comprising:
an annular cage member selectively insertable into the bore formed in the wellhead assembly, the annular cage member comprising, sidewalls that define an interior, and a flange that projects radially outward from a terminal end of the sidewalls and selectively land on an upper end of the wellhead assembly;

a cam element having a portion positioned in the interior of the cage member and that has a conically shaped outer periphery, the cam element being axially movable with respect to the cage member and the conically shaped outer periphery being in selective contact with the cage member;

an annular actuation member on a terminal end of the cage member and which circumscribes a portion of the cam element;

an annular seal between the cam element and an inner surface of the bore, the cam element selectively energizing the annular seal by compressing the annular seal axially with the actuation member to form a pressure barrier in the bore;

a locking assembly comprising a dog that projects radially outward through a sidewall of the cage member into selective engagement with a groove that circumscribes the bore; and

an actuation assembly coupled to the cam element so that when actuated, the actuation assembly moves the cam element axially relative to the annular cage member to compress the seal against the actuation member.

2. The tree cap assembly of claim 1, wherein the annular seal is formed of a material selected from the group consisting of lead, tin, silver, gold, and alloys thereof.

3. The tree cap assembly of claim 1, wherein the cam element receives pressure on a lower surface and from the bore to further compress the seal.

4. The tree cap assembly of claim 1, wherein the cam element comprises:
a stem extending from the bore to the actuation assembly through the interior of the cage member;

a medial portion mounted to the stem and having a conical surface that selectively engages the dog to drive the dog into the groove; and

a seal carrier portion mounted to the medial portion opposite the stem and configured to carry the annular seal and energize the annular seal in response to axial movement of the cam element.

5. The tree cap assembly of claim 1, the actuation assembly comprising:
a housing having a cavity; and

an axially moveable spreader plate positioned in the cavity, the spreader plate having a width substantially equivalent to a width of the cavity, the cam element coupled to the spreader plate so that

axial movement of the spreader plate moves the cam element to compress the annular seal against the actuation member.

6. The tree cap assembly of claim 5, wherein the actuation member depends from a lower end of the cage member.

7. The tree cap assembly of claim 5, the actuation assembly further comprising a mechanical energizer extending from a wall of the housing disposed proximate to a subsea tree when the tree cap lands on a tree head of the subsea tree to the spreader plate, the mechanical energizer configured to exert an axial force on the spreader plate to drive the spreader plate axially upward.

8. The tree cap assembly of claim 7, wherein the mechanical energizer is further configured to maintain an axial force on the spreader plate to maintain the annular seal in the energized position.

9. The tree cap assembly of claim 7, the actuation assembly further comprising a hydraulic actuator positioned opposite the mechanical energizer to move the spreader plate axially to compress the mechanical energizer to maintain the seal in the unset position during running and retrieval of the tree cap assembly.

10. The tree cap assembly of claim 1, wherein the actuation assembly comprises:
a housing having a cavity and configured to receive and direct hydraulic pressure;

a hydraulic piston having an actuation surface and a retrieval surface, the hydraulic piston positioned in a cavity of the housing and configured to move axially in response to application of hydraulic fluid pressure to the actuation and retrieval surfaces;

the cam element coupled to the hydraulic piston so that axial movement of the hydraulic piston moves the cam element to compress the annular seal against the actuation member; and

one or more valves actuable to selectively permit application of hydraulic fluid pressure to the actuation and retrieval surfaces of the hydraulic piston.

11. The tree cap assembly of claim 10, wherein the actuation assembly further comprises:
an accumulator to store at least one of hydraulic fluid pressure and gas pressure;

a charge valve in communication with the accumulator to selectively supply at least one of hydraulic fluid pressure and gas pressure to the accumulator and vent at least one of hydraulic fluid pressure and gas pressure from the accumulator;

an accumulator valve positioned between the accumulator and the actuation assembly and in communication with the actuation surface of the hydraulic piston to selectively allow communication between the accumulator and the actuation surface of the hydraulic piston;

wherein the accumulator, the charge valve, and the accumulator valve are configured to selectively apply at least one of hydraulic fluid pressure and gas pressure to the actuation surface of the hydraulic piston; and

wherein the application of at least one of hydraulic fluid pressure and gas pressure from the accumulator maintains the energization of the seal.

12. A tree cap assembly for capping a bore of a subsea wellhead assembly, the bore having an axis, the tree cap assembly comprising:
an annular cage member selectively insertable into the bore formed in the wellhead assembly, the annular cage having an interior;

an annular actuation member depending from a lower end of the cage member;

a cam element having a portion positioned in the interior of the cage member and axially movable with respect to the cage member;

an annular seal between the cam element and an inner surface of the bore, the cam element selectively energizing the annular seal by compressing the annular seal axially against the actuation member to form a pressure barrier in the bore;

a locking assembly comprising a dog that projects radially outward through a sidewall of the cage member into selective engagement with a groove that circumscribes the bore;

a housing having a cavity and configured to receive and direct hydraulic pressure;

a hydraulic piston having an actuation surface and a retrieval surface, the hydraulic piston positioned in a cavity of the housing and configured to move axially in response to application of hydraulic fluid pressure to the actuation and retrieval surfaces;

the cam element coupled to the hydraulic piston so that axial movement of the hydraulic piston moves the cam element to compress the annular seal against the actuation member by moving the cam element axially relative to the annular cage member;

one or more valves actuable to selectively permit application of hydraulic fluid pressure to the actuation and retrieval surfaces of the hydraulic piston.

an accumulator to store at least one of hydraulic fluid pressure and gas pressure;

a charge valve in communication with the accumulator to selectively supply at least one of hydraulic fluid pressure and gas pressure to the accumulator and vent at least one of hydraulic fluid pressure and gas pressure from the accumulator;

an accumulator valve positioned between the accumulator and the actuation assembly and in communication with the actuation surface of the hydraulic piston to selectively allow communication between the accumulator and the actuation surface of the hydraulic piston;

wherein the accumulator, the charge valve, and the accumulator valve are configured to selectively apply at least one of hydraulic fluid pressure and gas pressure to the actuation surface of the hydraulic piston; and

wherein the application of at least one of hydraulic fluid pressure and gas pressure from the accumulator maintains the energization of the seal.

13. The tree cap assembly of claim 12, wherein the annular seal is formed of a material selected from the group consisting of lead, tin, silver, gold, and alloys thereof.

14. The tree cap assembly of claim 12, wherein the cam element receives pressure on a lower surface and from the bore to further compress the seal.

15. The tree cap assembly of claim 12, wherein the cam element comprises:
a stem extending from the bore to the actuation assembly through the interior of the cage member;

a medial portion mounted to the stem and having a conical surface that selectively engages the dog to drive the dog into the groove; and

a seal carrier portion mounted to the medial portion opposite the stem and configured to carry the annular seal and energize the annular seal in response to axial movement of the cam element.

16. The tree cap assembly of claim 12, wherein the annular seal comprises a wedge-type cross sectional profile.

17. A method for capping and sealing a subsea tree including a tree head, a bore having an axis, and a locking groove formed therein, the method comprising:
(a) providing a subsea tree cap having a cam element carrying an annular metal seal having a wedge type profile, the cam element moveable along the axis of the bore;

(b) running the subsea tree cap to the subsea tree located proximate to the sea floor;

(c) positioning a portion of the cam element in the bore and lowering the subsea tree cap to land on the subsea tree;

(d) moving the cam element axially upward to secure the subsea tree cap to the subsea tree and deformingly engage the annular metal seal to seal to the subsea tree cap and the bore of the subsea tree; and

(e) slidingly engaging a medial portion of the cam element having a conical profile against a conical cam surface of an annular dog carried by the subsea tree cap to expand the annular dog radially into the locking groove of the bore.

18. The method of claim 17, wherein step (d) further comprises compressing the annular metal seal between a lower conical portion of the cam element and an actuation member depending from an outer diameter of a cage of the tree cap positioned in the bore of the subsea tree.

19. The method of claim 17, wherein step (d) further comprises removing hydraulic pressure from a hydraulic cylinder exerting a downward axial force on the cam element, thereby allowing a mechanical energizer coupled to the cam element to exert an upward axial force on the cam element.

20. The method of claim 17, wherein step (d) further comprises supplying hydraulic fluid pressure to a hydraulic piston coupled to the cam element to move the cam element axially upward and releasing gas pressure stored in an accumulator of the subsea tree cap to exert an upward axial force on the cam element that maintains the engagement of the seal to the bore.

21. The method of claim 17, further comprising maintaining an upward axial force on the hydraulic piston to accommodate for thermal expansion and contraction of the subsea tree and creep and stress relaxation of the annular seal.