Appendix A: Tables with background information on primary fabrics and common mineralogies in non-marine carbonate deposits.

Depositional environment	**Terminology of most commonly reported primary carbonate fabrics**	**Recent (active)**	**Fossil**
Caves	Coated grains; fibrous or columnar (including fascicular optic and radiaxial), dendritic and banded fan/ ray low- to high-Mg calcite or aragonite crystals (in stalagmites, stalagtites and flowstones); micrite; cave popcorn; moonmilk. Spheroidal crystal aggregates of (poorly ordered) dolomite, aragonite, calcite.	(Kendall and Broughton, 1978; Kendall, 1985, 1993; Frisia et al., 2000; Alonso-Zarza and Martín-Pérez, 2008; Woo et al., 2008; Pedley and Rogerson, 2010; Frisia and Borsato, 2010; Fairchild and Baker, 2012; Brasier et al., 2015; Richter et al., 2015; Frisia, 2015; Mart et al., 2015)	(Gonzalez and Lohmann, 1988; Frisia, 1996, 2015; Frisia and Borsato, 2010; Brasier, 2011; Richter et al., 2011)
Streams and springs	Mostly aragonite and calcite mineralogy. Micrite, microsparite or crystalline feather-like or dendritic crystal aggregates, fan or ray crystals, palisade crystals, micritic-microsparitic shrub crystal aggregates; micrite to sparite coated filaments, stems, bryophytes, foam rock (coated gas bubbles); rafts, microbial laminites (flat, curled; incl. stromatolites), thrombolites, peloids, diverse coated grains (radial spherulites, oncoids, ooids); litho-/extraclasts.	(Ford and Pedley, 1996; Freytet and Verrecchia, 1999; Arp et al., 2001; Kano et al., 2003; Pentecost, 2005; Pedley and Rogerson, 2010; Gradzinski, 2010; Jones and Renaut, 2010; Fouke, 2011; Okumura et al., 2012; Capezzuoli et al., 2014; Barth and Chafetz, 2015)	(Arp, 1995; Zamarreño et al., 1997; Guo and Riding, 1998; Pentecost, 2005; Brasier, 2011; Jones and Peng, 2012; Gandin and Capezzuoli, 2014; Lopez et al., 2017)
Marginal lacustrine	Aragonite, low- to high-Mg calcite, (poorly ordered) dolomite laminated microbialites (stromatolites), thrombolites, clotted peloidal micrite, micritic dendritic or shrub crystal aggregates; skeletal grains (charophytes, gastropods, ostracods); litho-/extraclasts; coated grains including spherulites, ooids; silicification.	(Platt and Wright, 1991; Freytet and Verrecchia, 2002; Verrecchia, 2007; Gierlowski-Kordesch, 2010; Della Porta, 2015; Chagas et al., 2016)	(Riding, 1979; Anadon et al., 1991; Platt and Wright, 1991; Arp, 1995; Wright et al., 1997; Harris, 2000; Freytet and Verrecchia, 2002; Seard et al., 2013; Frantz et al., 2014; Della Porta, 2015; Bouton et al., 2016; Rogerson et al., 2017; Mercedes-Martín et al., 2017)
Palustrine	Micritic nodules, brecciated limestone, mottled limestone, root molulds, alveolar structures, micro-karst, peloidal and (micritic) intraclastic limestone; skeletal grains (charophytes, gastropods, ostracods). Aragonite, calcite and dolomite mineralogies	(Freytet and Verrecchia, 2002; Alonso-Zarza, 2003)	(Fretyet and Plaziat, 1982; Platt and Wright, 1992)
Calcretes	Nodules/glaebules, clotted peloidal micrite, laminar crusts, hardpan, chalky micrite/microspar, alveolar septal structures, diverse coated grains, rhizoconcretions, lichen stromatolite, spherulites, calcite/(poorly ordered) dolomite mosaics forming crusts.	(Esteban and Klappa, 1983; Wright and Tucker, 1991; Alonso-Zarza, 2003; Armenteros, 2010; James and Jones, 2015)	(Esteban and Klappa, 1983; Wright and Tucker, 1991; Verrecchia et al., 1995; Armenteros, 2010)

Table A1: Overview of the range of commonly reported ‘primary’ carbonate micro- to macrofabrics in diverse non-marine carbonate depositional environments, as observed in the field and under transmitted light microscopy, plus key literature.

Mineral	Formula	Appearance	Physico-chemical conditions	References
Calcite	$CaCO_3$ (rhombohedral)	Rhombohedra, scalenohedra, prisms, micrite to sparite, granular, dendrite and shrub crystal aggregates, elongated columnar, ray crystals	Ambient to increased temperatures, low supersaturation polymorph, can become unfavorable under SO_4, Fe, high Mg (Mg/Ca>0.5) and Sr concentrations. When evolving from ACC, LMC and HMC may form from Mg/Ca: 0-4 (stirred) - up to 10 (quiescent conditions)	(Plummer and Busenberg, 1982; Gonzalez and Lohmann, 1988; Morse and Mackenzie, 1990; Frisia et al., 2002; Pentecost, 2005; Deocampo, 2010; Fouke, 2011; Riechelmann et al., 2014; Blue et al., 2017; Jones, 2017)
Aragonite	$CaCO_3$ (orthorhombic)	Often acicular, fibrous crystals forming botryoids or ray fans	Ambient to increased temperatures, high supersaturations (degassing), $SI_{calcite}<0.8$, elevated Mg/Ca (>0.5) or Mg/Ca ~ 5 when evolving from ACC (stirred conditions). Increased Sr, Ba, SO_4-ion concentrations favor aragonite over calcite.	(Plummer and Busenberg, 1982; Gonzalez and Lohmann, 1988; Morse and Mackenzie, 1990; Frisia et al., 2002; Kele et al., 2008; Deocampo, 2010; Fouke, 2011; Riechelmann et al., 2014; Sun et al., 2015; Jones and Peng, 2016; Blue et al., 2017; Jones, 2017)
Vaterite	$CaCO_3$ (hexagonal)	Precipitates most commonly form micron-size sphericoidal shapes	Atmospheric pressure (1 atm), low temperature (< 10°C), high supersaturation, alkaline solutions. May be favored in phosphorous-enriched media rapidly transforms in presence of water, often - not always - reported in association with organic molecules	(Plummer and Busenberg, 1982; Grasby, 2003; Sanchez-Moral et al., 2003; Rodriguez-Navarro et al., 2007; Wang and Becker, 2009; Rodriguez-Blanco et al., 2011)
Monohydrocalcite (MHC)	$CaCO_3$*H2O (hexagonal)	nanometer-sized crystals (<35 nm), or more commonly low angle branching spherulites with knobby crystal surface	Mg/Ca: 0.17 - 65, mostly favoured in high Mg/Ca fluids (>4), alkaline solutions ($aCO_3^{2-}/aCa^{2+} > 1.0$). Metastable (intermediate) polymorph, possibly evolving from ACC/Mg-ACC, and transforming (within hours) into anhydrous $CaCO_3$.	(Nishiyama et al., 2013; Demichelis et al., 2014; Rodriguez-Blanco et al., 2014; Blue et al., 2017)
Ikaite	$CaCO_3\cdot6H_2O$ (monoclinic)	White, square prisms and pyramidal crystals; blade and needle-like crystals. Recrystallizes into thinolites or glendonites (calcite pseudomorphs)	T~0°C, preferably < 6-7°C; becomes stable at ambient temperatures (25°C) when pressure >2-3 kbar. pH > 11. Can be favored in organic-rich sediments (presence of phosphate or amino acids that could inhibit anhydrous $CaCO_3$? No concensus yet). Ca-Na-$HC0_3$-rich, high alkalinity solutions (Ca > 30 mg/L) and microbial activity in anoxic conditions may promote ikaite. May form after ACC, but not necessary. Transforms rapidly (days) to calcite (and H_2O) under earth surface conditions.	(Suess et al., 1982; Shaikh and Shearman, 1986; Shearman et al., 1989; Council and Bennett, 1993; Whiticar and Suess, 1998; Buchardt et al., 2001; Shahar et al., 2005; Demichelis et al., 2014; Hu et al., 2014; Papadimitriou et al., 2014; Boch et al., 2015; Sánchez-Pastor et al., 2016; Peckmann, 2017)
Calcium-oxalate	$CaC_2O_4.H_2O$ and $CaC_2O_4.2H_2O$ Monoclinic or tetragonal	Monohydrate (whewellite): isodiametric (prisms or pseudo-rhombs) or elongated (spindles, dumbbells), Dihydrate or polyhydrate (weddellite): octahedral crystals, dipyramidal shapes, prisms, needles.	Strongly associated with fungi, trees, plant roots (in soils or spring carbonates): cellular carbohydrate is aerobically oxidized. Oxalic acid that is produced, reacts with Ca^{2+} (in tissue or environment) forming oxalic salts like Ca-oxalate. Ca-oxalate transforms rapidly to $CaCO_3$ upon death and oxidation of the organic tissue with O_2.	(Verrecchia and Dumont, 996; Cromack et al., 1977; Verrecchia et al., 1993; Freytet and Verrecchia, 1995; Horner and Wagner, 1995; Braissant et al., 2004; Cailleau et al., 2011, 2014)
Huntite	$CaMg_3(CO_3)_4$ (trigonal)	Platelets that can form globules and rosettes; chalk like masses	Cool temperature, Mg-rich fluids in lakes and final stage of crystallization sequences where increasingly Mg-rich phases form (eg in caves). In cases: microbially mediated or facilitated precipitation. Easily replacement by dolomite.	(Gonzalez and Lohmann, 1988; Alonso-Zarza and Martín-Pérez, 2008; Sánchez-Román et al., 2011)

Dolomite	$CaMg(CO_3)_2$ (trigonal)	Micritic, microscparitic, euhedral rhombohedra, sometimes forming spheroid and dumbbell structures	High Mg^{2+}/Ca^{2+}- ratios (2-7; <10); low Ca^{2+}/CO_3^{2-} ratios; salinities substantially lower or higher than that of seawater. Stable, ordered dolomite typically develops at higher temperatures. May evolve from Mg-ACC (v$MgCO_3$ 50%) at T>60°C. At surface conditions non-stoichiometric very high Mg-calcite and/or poorly ordered '(proto)dolomite' may form, often in relation to organic matter, low SO_4^{-2} concentrations, specific microbial metabolisms (including sulfate reduction). Can form as weathering product of huntite and hydromagnesite under aerobic, low temperature conditions.	(Vasconcelos et al., 1995; Vasconcelos and McKenzie, 1997; Machel, 2004; Alonso-Zarza and Martín-Pérez, 2008; Bontognali et al., 2010, 2014; Sánchez-Román et al., 2011; Kenward et al., 2013; Roberts et al., 2013; Richter et al., 2014; Gregg et al., 2015; Rodriguez-Blanco et al, 2015)
Hydromagnesite	$Mg(CO_3)4(OH) 2{\cdot}4H_2O$ (monoclinic)	Platy and acicular crystals, micritic	Low temperature, Mg-rich fluids (Mg/Ca > 39) in highly alkaline lakes and in crystallization sequences in cave deposits; in cases: microbially mediated or facilitated precipitation. Easily replaced by dolomite. May form as a byproduct of monohydrocalcite transformation to anhydrous $CaCO_3$.	(Gonzalez and Lohmann, 1988; Léveillé et al., 2000; Alonso-Zarza and Martín-Pérez, 2008; Sánchez-Román et al., 2011; Chagas et al., 2016)
Magnesite	$MgCO_3$ (trigonal)	Massive, micritic to coarsely crystalline, powdery, white to pale coloured	Extremely high Mg/Ca ratios in fluids in ultrabasic or dolomitic terrains, strong evaporation (?), dehydration of nesquehonite; microbially mediated or facilitated precipitation (?)	(Léveillé et al., 2000; Melezhik et al., 2001; Deocampo, 2010)

Table A2: Most common carbonate mineralogies, including Ca-oxalates, in non-marine carbonate deposits. Not included are currently rarely reported mineralogies like for example nesquehonite ($MgCO_3*3H_2O$). LMC = low-magnesium calcite; HMC = high-magnesium calcite; ACC = amorphous calcium carbonate; Mg-ACC = Mg-rich ACC.

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