W O R L D W I D E

wwPDB

P R O T E I N   D A T A   B A N K

wwPDB X-ray Structure Validation Summary Report (i)

Nov 11, 2025 – 02:11 PM EST

PDB ID	:	9DYP / pdb_00009dyp
Title	:	Crystal Structure of Rubisco from Methanococcoides burtonii
Authors	:	Pereira, J.H.; Liu, A.K.; Shih, P.M.; Adams, P.D.
Deposited on	:	2024-10-14
Resolution	:	1.50 Å(reported)

The following versions of software and data (see references (i)) were used in the production of this report:

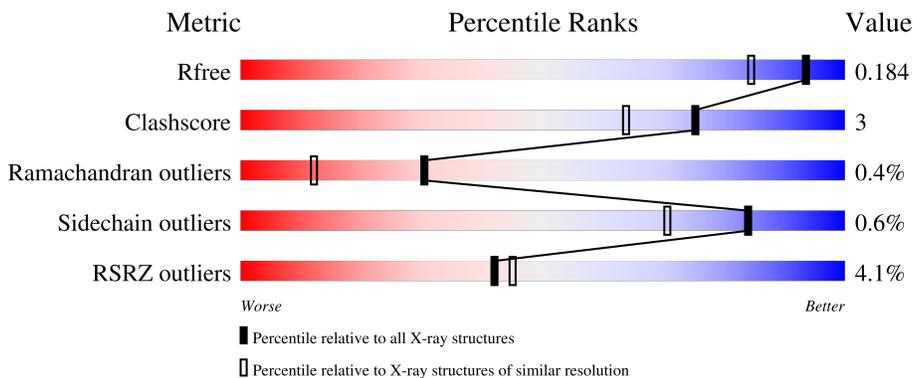|		
MolProbity	:	4-5-2 with Phenix2.0
Mogul	:	2022.3.0, CSD as543be (2022)
Xtriage (Phenix)	:	2.0
EDS	:	3.0
Percentile statistics	:	20231227.v01 (using entries in the PDB archive December 27th 2023)
CCP4	:	9.0.010 (Gargrove)
Density-Fitness	:	1.0.12
Ideal geometry (proteins)	:	Engh & Huber (2001)
Ideal geometry (DNA, RNA)	:	Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP)	:	2.46

1 Overall quality at a glance ⓘ

The following experimental techniques were used to determine the structure:
X-RAY DIFFRACTION

The reported resolution of this entry is 1.50 Å.

Percentile scores (ranging between 0-100) for global validation metrics of the entry are shown in the following graphic. The table shows the number of entries on which the scores are based.

Metric	Percentile Ranks	Value
Rfree		0.184
Clashscore		3
Ramachandran outliers		0.4%
Sidechain outliers		0.6%
RSRZ outliers		4.1%

Worse   *Better*

▮ Percentile relative to all X-ray structures
▯ Percentile relative to X-ray structures of similar resolution

Metric	Whole archive (#Entries)	Similar resolution (#Entries, resolution range(Å))
R$_{free}$	164625	3717 (1.50-1.50)
Clashscore	180529	4048 (1.50-1.50)
Ramachandran outliers	177936	3970 (1.50-1.50)
Sidechain outliers	177891	3967 (1.50-1.50)
RSRZ outliers	164620	3718 (1.50-1.50)

The table below summarises the geometric issues observed across the polymeric chains and their fit to the electron density. The red, orange, yellow and green segments of the lower bar indicate the fraction of residues that contain outliers for >=3, 2, 1 and 0 types of geometric quality criteria respectively. A grey segment represents the fraction of residues that are not modelled. The numeric value for each fraction is indicated below the corresponding segment, with a dot representing fractions <=5% The upper red bar (where present) indicates the fraction of residues that have poor fit to the electron density. The numeric value is given above the bar.

Mol	Chain	Length	Quality of chain
1	A	468	2% 94% 5%
1	B	468	6% 92% 6% •
1	C	468	5% 89% 8% ••
1	D	468	3% 91% 7% •

2 Entry composition ⓘ

There are 3 unique types of molecules in this entry. The entry contains 30207 atoms, of which 14198 are hydrogens and 0 are deuteriums.

In the tables below, the ZeroOcc column contains the number of atoms modelled with zero occupancy, the AltConf column contains the number of residues with at least one atom in alternate conformation and the Trace column contains the number of residues modelled with at most 2 atoms.

- Molecule 1 is a protein called ribulose-1,5-bisphosphate carboxylase.

Mol	Chain	Residues	Atoms						ZeroOcc	AltConf	Trace
1	A	468	Total	C	H	N	O	S	0	0	0
			7288	2353	3598	614	701	22			
1	B	463	Total	C	H	N	O	S	0	0	0
			7204	2326	3558	606	692	22			
1	C	459	Total	C	H	N	O	S	0	0	0
			7144	2310	3526	602	685	21			
1	D	457	Total	C	H	N	O	S	0	0	0
			7135	2309	3516	601	688	21			

- Molecule 2 is MAGNESIUM ION (CCD ID: MG) (formula: Mg) (labeled as "Ligand of Interest" by depositor).

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
2	A	1	Total	Mg	0	0
			1	1		
2	B	1	Total	Mg	0	0
			1	1		
2	C	1	Total	Mg	0	0
			1	1		
2	D	1	Total	Mg	0	0
			1	1		

- Molecule 3 is water.

| Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
3	A	377	Total	O	0	0
			377	377		
3	B	356	Total	O	0	0
			356	356		
3	C	319	Total	O	0	0
			319	319		
3	D	380	Total	O	0	0
			380	380		

3 Residue-property plots ⓘ

These plots are drawn for all protein, RNA, DNA and oligosaccharide chains in the entry. The first graphic for a chain summarises the proportions of the various outlier classes displayed in the second graphic. The second graphic shows the sequence view annotated by issues in geometry and electron density. Residues are color-coded according to the number of geometric quality criteria for which they contain at least one outlier: green = 0, yellow = 1, orange = 2 and red = 3 or more. A red dot above a residue indicates a poor fit to the electron density (RSRZ > 2). Stretches of 2 or more consecutive residues without any outlier are shown as a green connector. Residues present in the sample, but not in the model, are shown in grey.
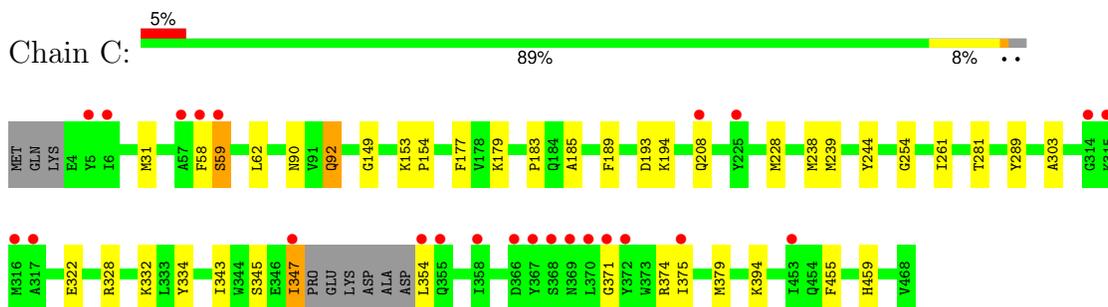
- Molecule 1: ribulose-1,5-bisphosphate carboxylase
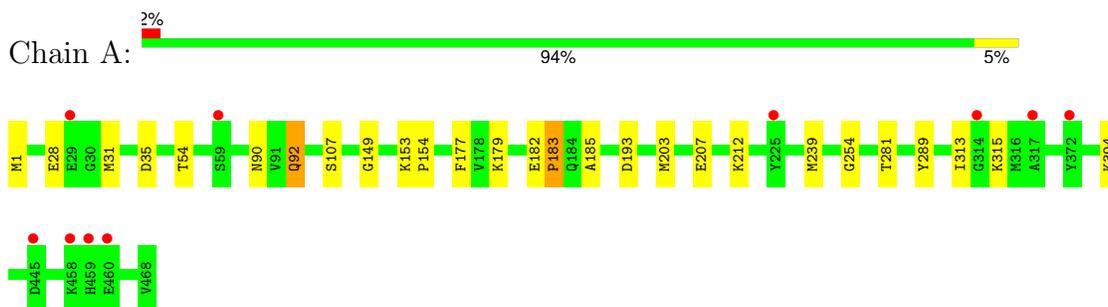
Chain A:
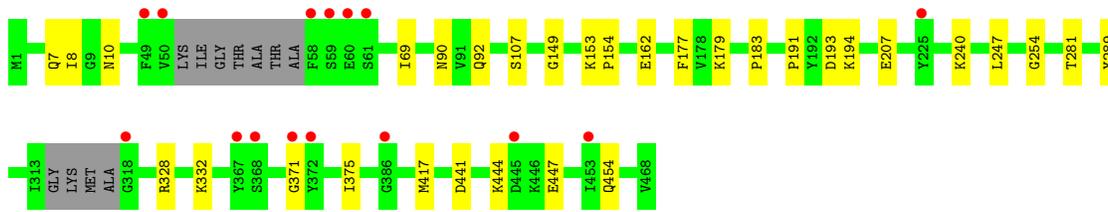

- Molecule 1: ribulose-1,5-bisphosphate carboxylase

Chain B:

- Molecule 1: ribulose-1,5-bisphosphate carboxylase

Chain C:

- Molecule 1: ribulose-1,5-bisphosphate carboxylase

Chain D:
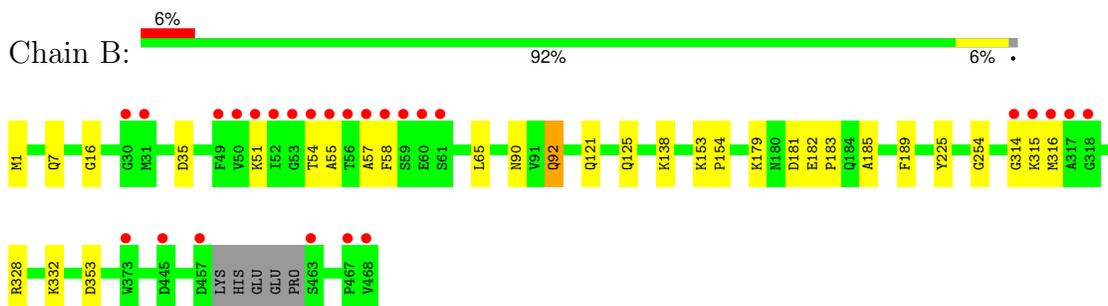
4 Data and refinement statistics ⓘ

Property	Value	Source
Space group	P 1 21 1	Depositor
Cell constants a, b, c, α, β, γ	86.03Å 102.82Å 97.73Å 90.00° 90.14° 90.00°	Depositor
Resolution (Å)	45.50 – 1.50 45.50 – 1.50	Depositor EDS
% Data completeness (in resolution range)	99.9 (45.50-1.50) 99.9 (45.50-1.50)	Depositor EDS
R_{merge}	(Not available)	Depositor
R_{sym}	(Not available)	Depositor
$< I/\sigma(I) >$ [1]	0.68 (at 1.50Å)	Xtriage
Refinement program	PHENIX 1.21.2_5419	Depositor
R, R_{free}	0.162 , 0.186 0.162 , 0.184	Depositor DCC
R_{free} test set	2018 reflections (0.74%)	wwPDB-VP
Wilson B-factor (Å^2)	16.2	Xtriage
Anisotropy	0.305	Xtriage
Bulk solvent k_{sol}(e/Å^3), B_{sol}(Å^2)	0.43 , 40.7	EDS
L-test for twinning[2]	$< |L| > = 0.49$, $< L^2 > = 0.32$	Xtriage
Estimated twinning fraction	0.012 for -h,-l,-k 0.000 for -h,l,k 0.023 for h,-k,-l	Xtriage
F_o,F_c correlation	0.97	EDS
Total number of atoms	30207	wwPDB-VP
Average B, all atoms (Å^2)	25.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The analyses of the Patterson function reveals a significant off-origin peak that is 20.96 % of the origin peak, indicating pseudo-translational symmetry. The chance of finding a peak of this or larger height randomly in a structure without pseudo-translational symmetry is equal to 7.7590e-03. The detected translational NCS is most likely also responsible for the elevated intensity ratio.*

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[1]Intensities estimated from amplitudes.
[2]Theoretical values of $< |L| >$, $< L^2 >$ for acentric reflections are 0.5, 0.333 respectively for untwinned datasets, and 0.375, 0.2 for perfectly twinned datasets.

5 Model quality ⓘ

5.1 Standard geometry ⓘ

Bond lengths and bond angles in the following residue types are not validated in this section: MG, KCX

The Z score for a bond length (or angle) is the number of standard deviations the observed value is removed from the expected value. A bond length (or angle) with $|Z| > 5$ is considered an outlier worth inspection. RMSZ is the root-mean-square of all Z scores of the bond lengths (or angles).

Mol	Chain	Bond lengths		Bond angles	
		RMSZ	#$|Z|$ >5	RMSZ	#$|Z|$ >5
1	A	0.37	1/3766 (0.0%)	0.57	1/5091 (0.0%)
1	B	0.30	0/3719	0.52	0/5026
1	C	0.30	0/3692	0.52	0/4991
1	D	0.35	0/3693	0.56	0/4991
All	All	0.33	1/14870 (0.0%)	0.54	1/20099 (0.0%)

All (1) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
1	A	193	ASP	C-O	-6.00	1.17	1.24

All (1) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
1	A	193	ASP	CA-CB-CG	6.37	118.97	112.60

There are no chirality outliers.

There are no planarity outliers.

5.2 Too-close contacts ⓘ

In the following table, the Non-H and H(model) columns list the number of non-hydrogen atoms and hydrogen atoms in the chain respectively. The H(added) column lists the number of hydrogen atoms added and optimized by MolProbity. The Clashes column lists the number of clashes within the asymmetric unit, whereas Symm-Clashes lists symmetry-related clashes.

Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
1	A	3690	3598	3598	15	0
1	B	3646	3558	3558	19	0

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Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
1	C	3618	3526	3525	28	0
1	D	3619	3516	3515	24	0
2	A	1	0	0	0	0
2	B	1	0	0	0	0
2	C	1	0	0	0	0
2	D	1	0	0	0	0
3	A	377	0	0	3	2
3	B	356	0	0	5	2
3	C	319	0	0	6	0
3	D	380	0	0	7	1
All	All	16009	14198	14196	82	3

The all-atom clashscore is defined as the number of clashes found per 1000 atoms (including hydrogen atoms). The all-atom clashscore for this structure is 3.

The worst 5 of 82 close contacts within the same asymmetric unit are listed below, sorted by their clash magnitude.

Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:D:328:ARG:HD3	1:D:332:LYS:HD2	1.74	0.69
1:D:193:ASP:OD1	1:D:194:LYS:HD2	1.92	0.68
1:C:322:GLU:OE2	3:C:601:HOH:O	2.13	0.67
1:B:353:ASP:OD1	3:B:601:HOH:O	2.14	0.66
1:D:207:GLU:OE1	3:D:601:HOH:O	2.14	0.65

All (3) symmetry-related close contacts are listed below. The label for Atom-2 includes the symmetry operator and encoded unit-cell translations to be applied.

Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
3:A:613:HOH:O	3:A:747:HOH:O[2_555]	2.11	0.09
3:B:938:HOH:O	3:D:960:HOH:O[1_655]	2.14	0.06
3:A:926:HOH:O	3:B:854:HOH:O[2_555]	2.19	0.01

5.3 Torsion angles ⓘ

5.3.1 Protein backbone ⓘ

In the following table, the Percentiles column shows the percent Ramachandran outliers of the chain as a percentile score with respect to all X-ray entries followed by that with respect to entries of similar resolution.

The Analysed column shows the number of residues for which the backbone conformation was analysed, and the total number of residues.

Mol	Chain	Analysed	Favoured	Allowed	Outliers	Percentiles	
1	A	465/468 (99%)	450 (97%)	13 (3%)	2 (0%)	30	12
1	B	458/468 (98%)	440 (96%)	16 (4%)	2 (0%)	30	12
1	C	454/468 (97%)	440 (97%)	11 (2%)	3 (1%)	19	5
1	D	450/468 (96%)	434 (96%)	15 (3%)	1 (0%)	44	22
All	All	1827/1872 (98%)	1764 (97%)	55 (3%)	8 (0%)	30	12

5 of 8 Ramachandran outliers are listed below:

Mol	Chain	Res	Type
1	C	59	SER
1	A	183	PRO
1	B	54	THR
1	B	185	ALA
1	A	185	ALA

5.3.2   Protein sidechains ⓘ

In the following table, the Percentiles column shows the percent sidechain outliers of the chain as a percentile score with respect to all X-ray entries followed by that with respect to entries of similar resolution.

The Analysed column shows the number of residues for which the sidechain conformation was analysed, and the total number of residues.

Mol	Chain	Analysed	Rotameric	Outliers	Percentiles	
1	A	388/388 (100%)	386 (100%)	2 (0%)	86	75
1	B	383/388 (99%)	381 (100%)	2 (0%)	86	75
1	C	380/388 (98%)	377 (99%)	3 (1%)	79	62
1	D	382/388 (98%)	380 (100%)	2 (0%)	86	75
All	All	1533/1552 (99%)	1524 (99%)	9 (1%)	84	70

5 of 9 residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	D	92	GLN
1	D	454	GLN
1	B	92	GLN

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Mol	Chain	Res	Type
1	C	92	GLN
1	C	208	GLN

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. 5 of 7 such sidechains are listed below:

Mol	Chain	Res	Type
1	B	17	GLN
1	B	369	ASN
1	D	197	GLN
1	D	121	GLN
1	A	208	GLN

5.3.3   RNA ⓘ

There are no RNA molecules in this entry.

5.4   Non-standard residues in protein, DNA, RNA chains ⓘ

4 non-standard protein/DNA/RNA residues are modelled in this entry.

In the following table, the Counts columns list the number of bonds (or angles) for which Mogul statistics could be retrieved, the number of bonds (or angles) that are observed in the model and the number of bonds (or angles) that are defined in the Chemical Component Dictionary. The Link column lists molecule types, if any, to which the group is linked. The Z score for a bond length (or angle) is the number of standard deviations the observed value is removed from the expected value. A bond length (or angle) with $|Z| > 2$ is considered an outlier worth inspection. RMSZ is the root-mean-square of all Z scores of the bond lengths (or angles).

Mol	Type	Chain	Res	Link	Bond lengths			Bond angles		
					Counts	RMSZ	$\#|Z| > 2$	Counts	RMSZ	$\#|Z| > 2$
1	KCX	D	179	1,2	10,11,12	1.86	2 (20%)	6,12,14	0.59	0
1	KCX	B	179	1,2	10,11,12	2.04	2 (20%)	6,12,14	0.71	0
1	KCX	A	179	1,2	10,11,12	1.99	2 (20%)	6,12,14	1.54	1 (16%)
1	KCX	C	179	1,2	10,11,12	1.91	2 (20%)	6,12,14	1.31	1 (16%)

In the following table, the Chirals column lists the number of chiral outliers, the number of chiral centers analysed, the number of these observed in the model and the number defined in the Chemical Component Dictionary. Similar counts are reported in the Torsion and Rings columns. '-' means no outliers of that kind were identified.

Mol	Type	Chain	Res	Link	Chirals	Torsions	Rings
1	KCX	D	179	1,2	-	0/9/10/12	-
1	KCX	B	179	1,2	-	0/9/10/12	-
1	KCX	A	179	1,2	-	0/9/10/12	-
1	KCX	C	179	1,2	-	0/9/10/12	-

The worst 5 of 8 bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
1	A	179	KCX	CX-NZ	5.05	1.44	1.35
1	C	179	KCX	CX-NZ	4.93	1.44	1.35
1	B	179	KCX	CX-NZ	4.83	1.43	1.35
1	D	179	KCX	CX-NZ	4.58	1.43	1.35
1	B	179	KCX	OQ1-CX	3.48	1.28	1.21

All (2) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
1	A	179	KCX	OQ1-CX-NZ	-3.52	119.57	124.92
1	C	179	KCX	OQ1-CX-NZ	-3.10	120.21	124.92

There are no chirality outliers.

There are no torsion outliers.

There are no ring outliers.

No monomer is involved in short contacts.

5.5 Carbohydrates ⓘ

There are no oligosaccharides in this entry.

5.6 Ligand geometry ⓘ

Of 4 ligands modelled in this entry, 4 are monoatomic - leaving 0 for Mogul analysis.

There are no bond length outliers.

There are no bond angle outliers.

There are no chirality outliers.

There are no torsion outliers.

There are no ring outliers.

No monomer is involved in short contacts.

WORLDWIDE
wwPDB
PROTEIN DATA BANK

5.7 Other polymers ⓘ

There are no such residues in this entry.

5.8 Polymer linkage issues ⓘ

There are no chain breaks in this entry.

6 Fit of model and data (i)

6.1 Protein, DNA and RNA chains (i)

In the following table, the column labelled '#RSRZ> 2' contains the number (and percentage) of RSRZ outliers, followed by percent RSRZ outliers for the chain as percentile scores relative to all X-ray entries and entries of similar resolution. The OWAB column contains the minimum, median, 95th percentile and maximum values of the occupancy-weighted average B-factor per residue. The column labelled 'Q< 0.9' lists the number of (and percentage) of residues with an average occupancy less than 0.9.

Mol	Chain	Analysed	<RSRZ>	#RSRZ>2			OWAB(Å^2)	Q<0.9
1	A	467/468 (99%)	-0.43	10 (2%)	63	66	12, 20, 40, 93	0
1	B	462/468 (98%)	-0.16	26 (5%)	31	33	14, 22, 47, 109	0
1	C	458/468 (97%)	-0.10	24 (5%)	34	35	14, 25, 53, 84	0
1	D	456/468 (97%)	-0.39	15 (3%)	49	52	12, 19, 41, 124	0
All	All	1843/1872 (98%)	-0.27	75 (4%)	42	45	12, 21, 46, 124	0

The worst 5 of 75 RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	D	50	VAL	8.2
1	B	52	ILE	7.4
1	B	55	ALA	6.5
1	D	58	PHE	5.9
1	B	57	ALA	5.4

## 6.2 Non-standard residues in protein, DNA, RNA chains (i)

In the following table, the Atoms column lists the number of modelled atoms in the group and the number defined in the chemical component dictionary. The B-factors column lists the minimum, median, 95th percentile and maximum values of B factors of atoms in the group. The column labelled 'Q< 0.9' lists the number of atoms with occupancy less than 0.9.

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(Å^2)	Q<0.9
1	KCX	A	179	12/13	0.98	0.04	12,14,17,17	0
1	KCX	C	179	12/13	0.98	0.04	15,19,21,21	0
1	KCX	D	179	12/13	0.98	0.04	10,12,14,14	0
1	KCX	B	179	12/13	0.99	0.03	12,14,17,17	0

6.3 Carbohydrates ⓘ

There are no oligosaccharides in this entry.

6.4 Ligands ⓘ

In the following table, the Atoms column lists the number of modelled atoms in the group and the number defined in the chemical component dictionary. The B-factors column lists the minimum, median, 95th percentile and maximum values of B factors of atoms in the group. The column labelled 'Q< 0.9' lists the number of atoms with occupancy less than 0.9.

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(Å^2)	Q<0.9
2	MG	D	501	1/1	0.97	0.04	11,11,11,11	0
2	MG	C	501	1/1	0.99	0.04	18,18,18,18	0
2	MG	A	501	1/1	1.00	0.01	12,12,12,12	0
2	MG	B	501	1/1	1.00	0.02	13,13,13,13	0

The following is a graphical depiction of the model fit to experimental electron density of all instances of the Ligand of Interest. In addition, ligands with molecular weight > 250 and outliers as shown on the geometry validation Tables will also be included. Each fit is shown from different orientation to approximate a three-dimensional view.
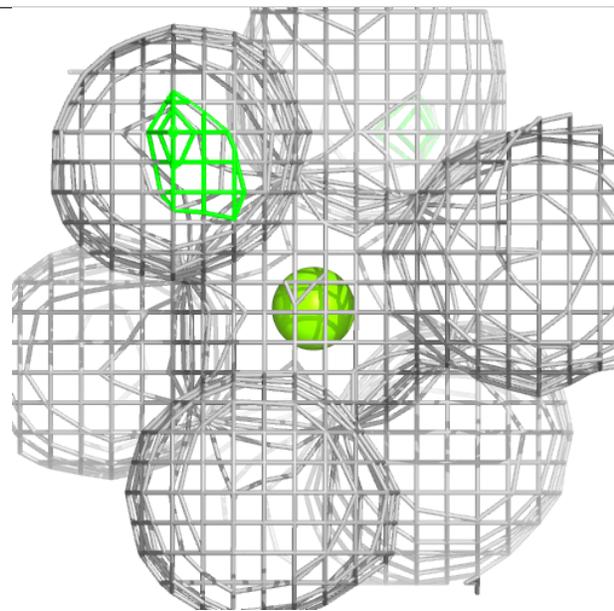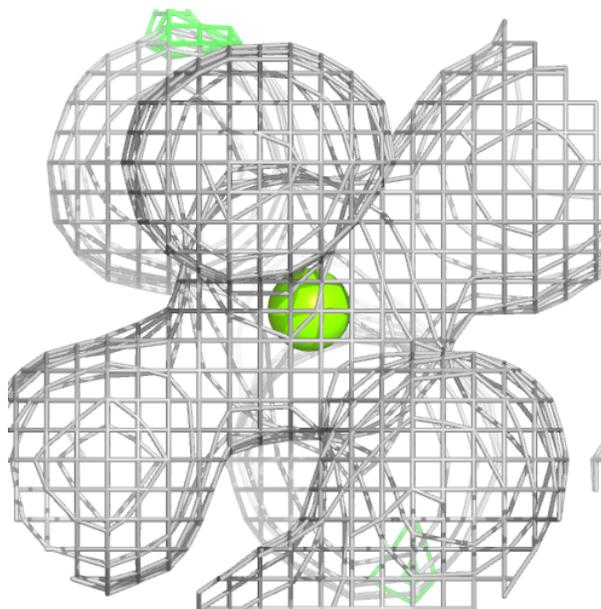
Electron density around MG D 501:

$2mF_o\text{-}DF_c$ (at 0.7 rmsd) in gray
$mF_o\text{-}DF_c$ (at 3 rmsd) in purple (negative)
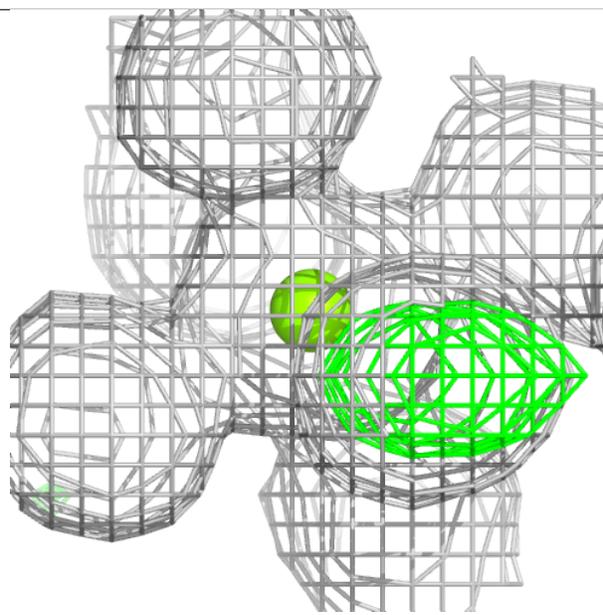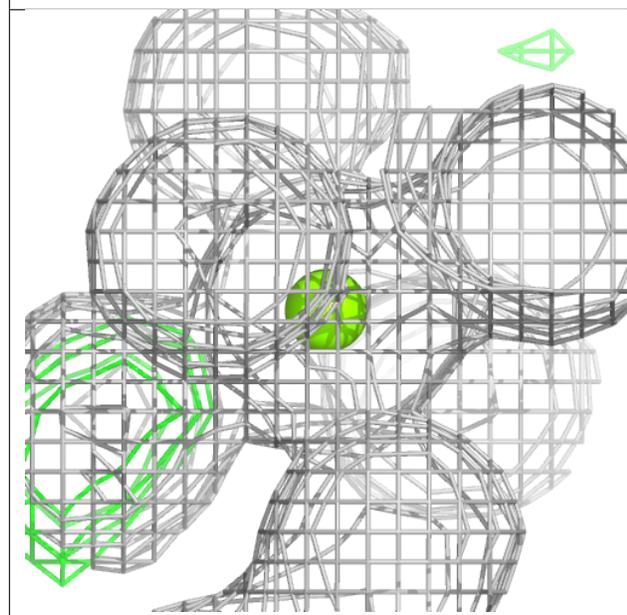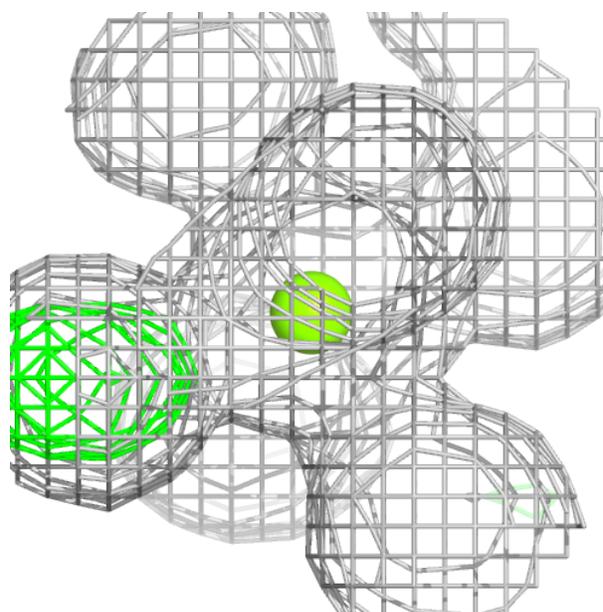and green (positive)
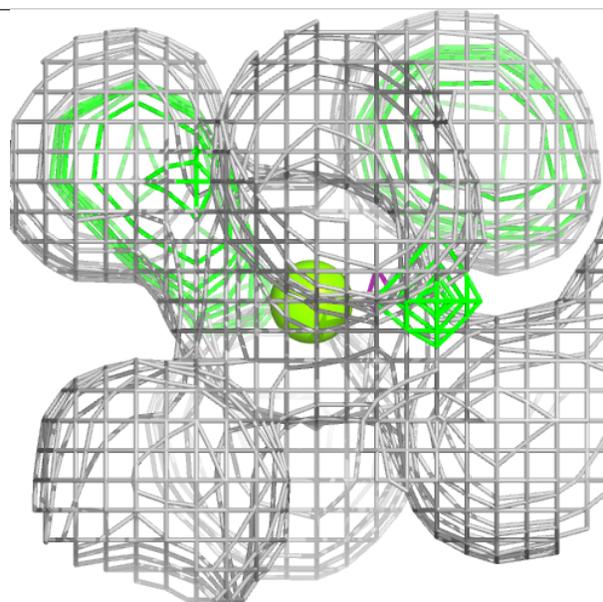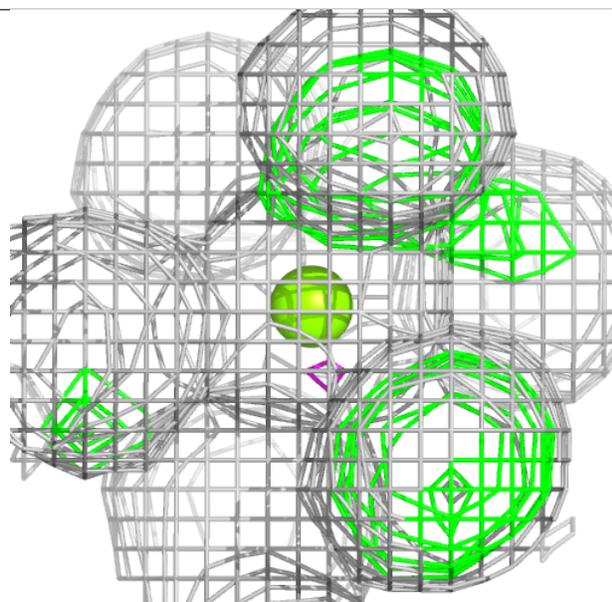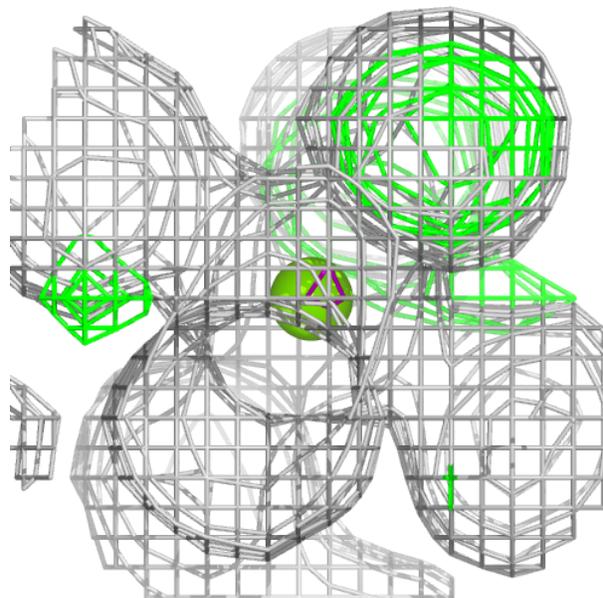
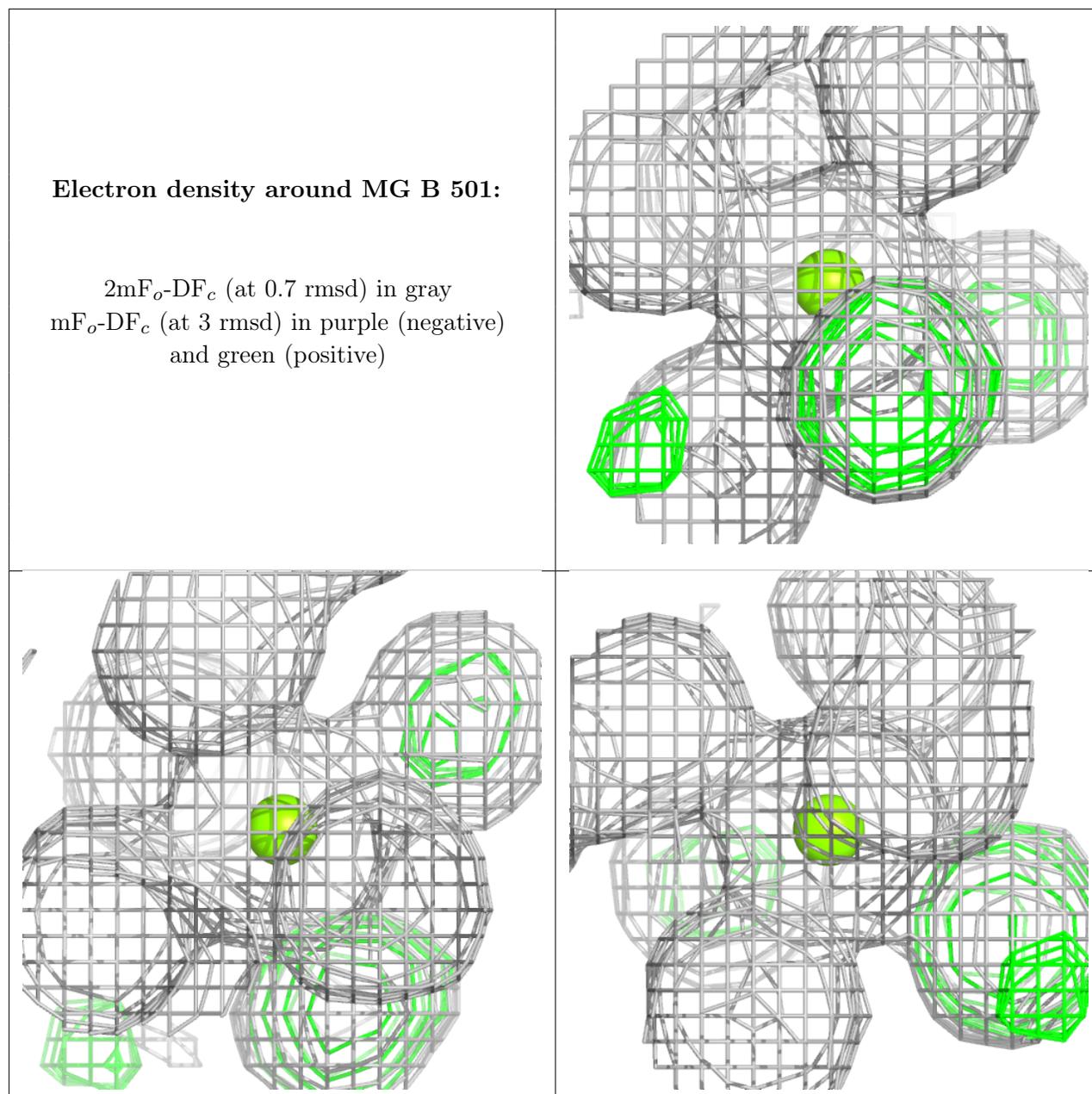**Electron density around MG C 501:**

$2mF_o\text{-}DF_c$ (at 0.7 rmsd) in gray
$mF_o\text{-}DF_c$ (at 3 rmsd) in purple (negative)
and green (positive)
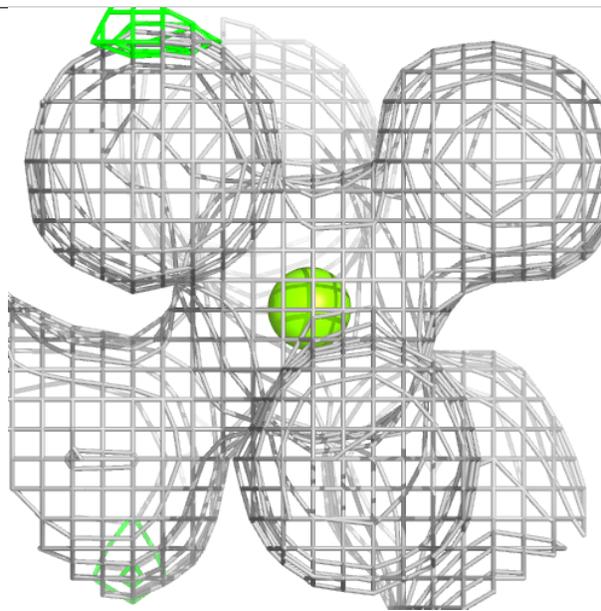
Electron density around MG A 501:

$2mF_o\text{-}DF_c$ (at 0.7 rmsd) in gray
$mF_o\text{-}DF_c$ (at 3 rmsd) in purple (negative)
and green (positive)

Electron density around MG B 501:

$2mF_o$-DF_c (at 0.7 rmsd) in gray
mF_o-DF_c (at 3 rmsd) in purple (negative)
and green (positive)

6.5 Other polymers ⓘ

There are no such residues in this entry.